EM-Phantom

User Manual V 4.1

Schmid & Partner Engineering AG

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Chapter 1

POPEYE V5.x

Figure 1.1: Posable phantom POPEYE V5.x

1.1 Introduction

The POsable Phantom for Electromagnetic sYstems Evaluations (POPEYE V5.x) is an anatomically phantom with posable arms, hands, and legs. It has been designed to meet the requirements for test configurations for which the effects of the body on the electromagnetic (EM) performance cannot be neglected, such as for operating tablet and laptop computers and other body-mounted transmitters. With a simple adjustment (one tightening screw), the arms, hands, and legs can be positioned accordingly for conducting simulations of any usage or operation (standing, sitting, arms raised, talking position, etc...). The dimensions have been chosen to meet the requirements for conservative testing.

The Whole-Body EM Phantom POPEYE V5.x consists of:

- Torso phantom TORSO-X-V5.x
- Posable right arm ARMR-V5.x
- Posable left arm ARML-V5.x
- Posable right leg LEGR-V5.x
- Posable left leg LEGL-V5.x
- Buttocks phantom BUTT-V5.x
- Right foot JIAOR-V5.x
- Left foot JIAOL-V5.x
- Right hand SHO-V2R/X
- Left hand SHO-V2L/X

Please read the following cautions and warnings before continue with the individual whole-body EM phantoms description.

1.2 Cautions and Warnings

Caution: The complete Whole-Body EM Phantom POPEYE V5.x weight > 80kg. Appropriate procedures for sage lifting should be followed (see Section 1.9).

Warning: The knobs used to adjust the arms and legs should never be removed.

Warning: Pose the joints only when the knob is loosen (but not removed), and never force a pose. Especially critical parts are the hand adapters, see Section 1.4.2.

1.3 Torso Phantom

1.3.1 Introduction

The torso phantom TORSO-X-V5.x is an anthropomorphically shaped shell phantom that has been developed for EM evaluations for which the effects of the body cannot be neglected, such as hand-held devices and on- or in-body mounted transmitters. The solid bottom plate has grip handles for easy positioning and handling.

Figure 1.2: Torso phantom TORSO-X-V5.xwith left arm phantom and left PDA hand phantom

The torso phantom TORSO-X-V5.x can be upgraded with additional phantom body parts such as arms, hands, legs, and feet (e.g., Figure 1.2).

1.3.2 Construction

The high-precision shell of the torso is manufactured from a vinylester-reinforced fiberglass structure. The torso phantom TORSO-X-V5.x can be filled with a broadband tissue simulating gel that complies with the dielectric target parameters of CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.2.1 (March 2013) over a wide frequency range. The parameters of the gel or tissue simulating liquids are verified at 22.0°C. The maximum allowed operating temperature is 40.0°C. The torso shall be stored at room temperature around 22°C. It must not be exposed to temperatures >30°C or <2°C or to sunlight radiation (heating).

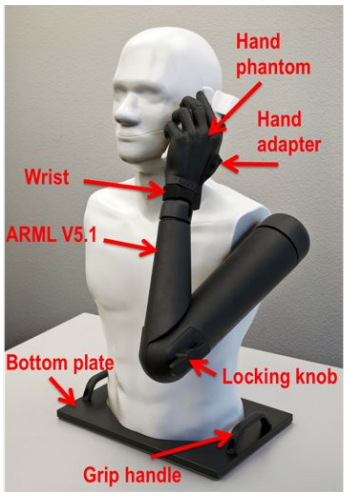


Figure 1.3: Torso phantom TORSO-X-V5.x parts

1.3.3 Dimensions

The head of the torso phantom TORSO-X-V5.x is compliant with the geometric data as defined by IEEE SCC34 and 3GPP TR25.914. The dimensions of the torso have been chosen to meet the requirements for conservative testing [1].

1.3.4 Operation

Torso phantom TORSO-X-V5.x can be used self-supported on the solid bottom plate. The solid bottom plate has grip handles for easy handling and positioning on a turntable or any positioner that can support a weight > 40 kg.

Note: For safe transport of torso phantom TORSO-X-V5.x, it is strongly recommended the torso phantom be packed in the same packing material in which it was delivered.

1.3.4.1 Torso Phantom - Filled with Tissue Simulating Gel

The torso phantom filled with tissue simulating gel is ready to use. The bottom plate (see Figure 1.3) must not be removed from the torso to prevent alteration or contamination of the filling gel material.

1.3.4.2 Empty Torso Phantom and Filling Procedure

The empty torso phantom can be filled with tissue simulation liquids as described below. The bottom plate (see Figure 1.3) must not be removed from the torso since the plate is sealed to prevent leakage. The torso phantom is

filled by way of the apertures on the bottom plate. When the torso is not in use, it is recommended to empty it as described below, rinse with hot water and keep the apertures open for drying to prevent contamination.

The following describes how to fill and empty the torso. Both procedures require a foam base to position the torso upside down, pliers, and a funnel to fill the liquid (all delivered with the torso).

Filling the Torso

1. Place the foam base on the floor and position the torso upside down into the foam base. Please make sure that it remains stable as shown in Figure 1.4. Use additional supports if necessary.

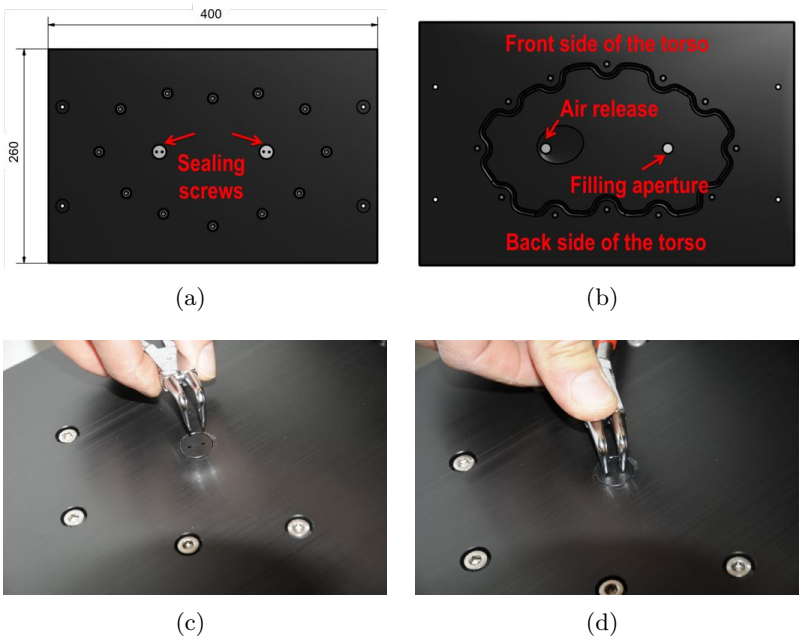
(a) (b)

Figure 1.4: (a) Foam base with cavity, (b) torso positioned upside down

2. The bottom plate is fixed with 12 screws that follow the contour of the torso (Figure 1.5). **Do not remove these 12 screws.** Within this contour there are two screws that seal the filling and air release apertures (Figure 1.5(b)). Remove both screws with the pliers as shown in Figure 1.5.

3. The aperture on the right side (see Figure 1.6 (a)) is for air release. Insert the funnel into the left aperture as shown in Figure 1.6and fill the torso through the funnel.

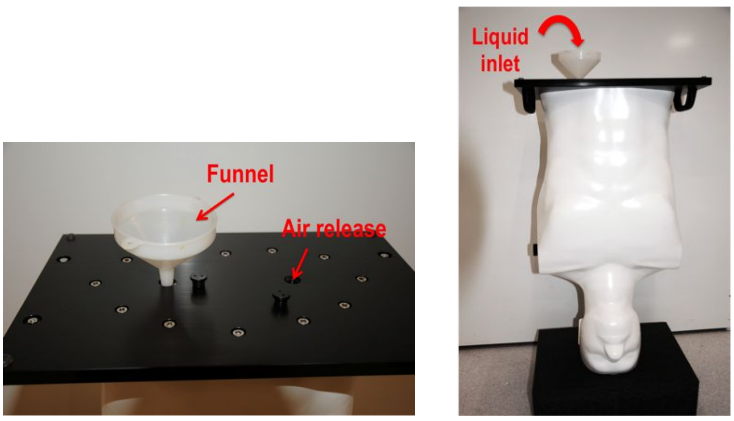
4. After torso is completely filled, close both apertures by re-inserting the screws, and tighten them with the pliers as shown in Figure 1.7. The torso is ready to be mounted according your requirements.



(a) (b)

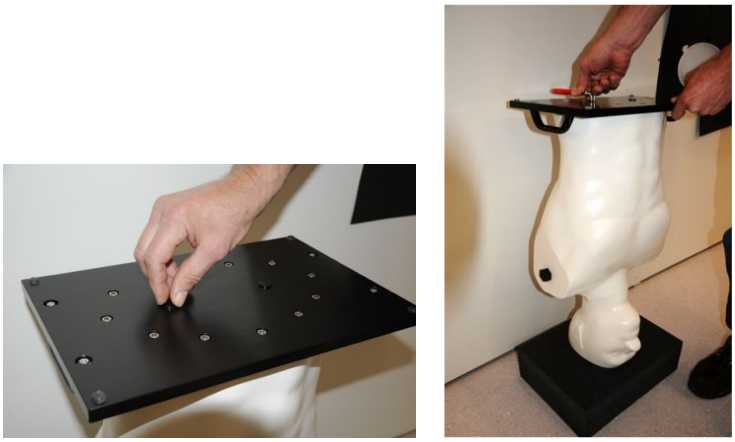
(c) (d)

Figure 1.5: (a) The outer and (b) inner surfaces of the bottom plate, (c)-(d) removing both screws using pliers



(a) (b)

Figure 1.6: Inserting the funnel into the corresponding aperture

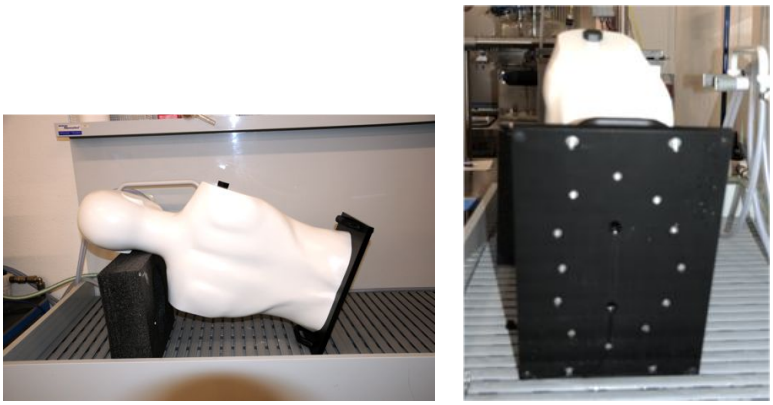


(a) (b)

Figure 1.7: Closing the openings and tightening the screws with the pliers

Emptying the Torso

1. Ensure that you have the appropriate environment, i.e., a container in which to empty 28 liters of tissue simulating liquid. Prepare a container to store the liquid or follow appropriate procedures to dispose the liquid (refer to the safety sheet of the liquid in use).



(a) (b)

Figure 1.8: Emptying the torso phantom liquid

2. Position the torso as shown in Figure 1.4 (a) and open two screws (see Figure 1.5 (a)) as shown in Figure 1.5 (c) and (d).

3. Position the torso as shown in Figure 1.8 (a) so that the liquid can drain into the prepared sink.

4. **Clean the inside of the torso with hot water and let it dry by leaving both the filling and air apertures open and exposed to air circulation.**

1.4 Arm Phantom

The posable right and left arms ARMR-V5.x (ARM Right) and ARML-V5.x (ARM Left) are generic right and left arm phantoms consisting of an outer bulk part manufactured from a silicone- and carbon-based mixture (with material target parameters given in CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.2.1 (March 2013)) and an inner low-loss dielectric structure with joints. With this architecture, the arm phantoms are suitable for EM evaluations above 500 MHz. The arm phantoms can be easily attached to the torso phantom TORSO-X-V5.x, and every SPEAG hand phantom can be attached to the arm with adapters that allow realistic human arm postures to be mimicked. Figure 1.3 shows an overview of torso and arm V5.1 parts.

1.4.1 Mounting the Arm

The following describes how the arm is mechanically attached to the torso. Once attached, the arm can be positioned in any posture. Installation requires two metric wrenches with sizes of 20 and 30 mm.

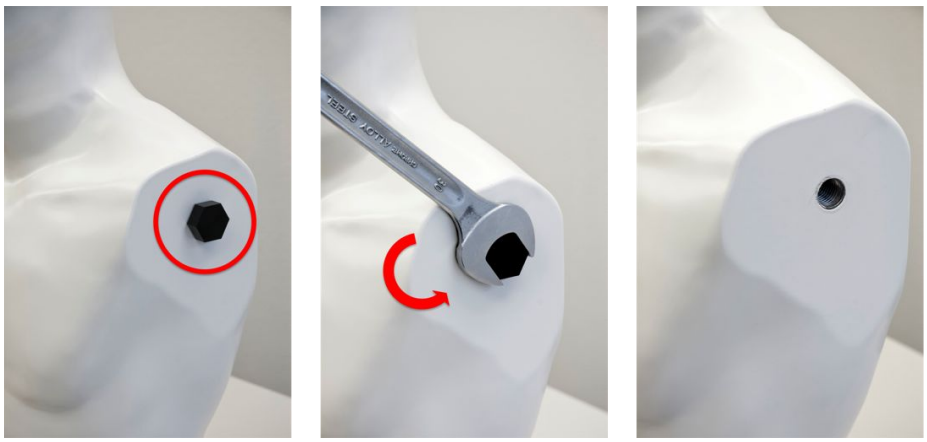
1. Ensure that the left and right arms are being attached to the correct sides of the torso.

2. The arm is attached while in a straightened position. Place the arm on a table and loosen the locking knob on the elbow. Extend the arm to a straight position and tighten the locking knob (Figure 1.9).

(a) (b)

Figure 1.9: (a) Loosening the locking knob on the elbow and (b) posing the arm into a straight position

3. The 30 mm wrench is used to loosen the black screw on the left and/or right side of the torso as shown in Figure 1.10. Remove the screw completely. Proceed to step 4 quickly to minimise exposure time of the filling gel to the air through the bolt hole.



(a) (b) (c)

Figure 1.10: Removing the black screw using 30 mm wrench

4. Mount the arm to the torso by screwing it manually into the bolt hole. Then, use the 20 mm wrench to securely fasten it as shown in Figure 1.11.

(a) (b)

Figure 1.11: Mounting the arm into the torso manually and then tightening with a 20 mm wrench

5. The lower half of the arm should always be supported when the locking knob on the elbow is loosened, which allows all three joints (shoulder, elbow, and wrist) to be freely rotated. Position the arm to your desired posture and tighten the locking knob.

6. Figure 1.12 shows how to mount the wrist to the arm. The wrist can

be simply screwed to the tip of the arm and tightened manually.

(a) (b)

(c)

Figure 1.12: Mounting the wrist to the tip of the arm

1.4.2 Mounting the Hand

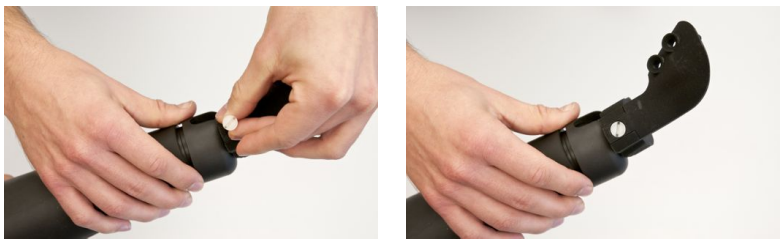
Every SPEAG hand phantom can be attached to the arm phantoms V5.x (ARMR-V5.x/ARML-V5.x) with the corresponding adapters. The adapter is first mounted on the arm phantom, and subsequently the hand phantom is mounted to the adapter.

The following describes how a PDA hand is mechanically mounted to the arm. Installation requires one flathead screwdriver. Please follow the same procedure for all other hand phantoms.

Mounting the PDA Hand Phantom to the Arm Phantom

1. Insert the PDA hand adapter into the wrist as shown in Figure 1.13 (a) and (b). Fix it with the 20 mm screw provided as shown in Figure 1.13 (c) and (d).
2. There are four holes in the PDA hand. Insert the hand adapter into the outermost holes of the hand as shown in Figure 1.14.
3. Insert 61 mm screws into the remaining holes and tighten them to mount the hand to the arm (Figure 1.15).
4. The lower half of the arm should always be supported when the locking knob on the elbow is loosened, which allows all three joints (shoulder,

(a) (b)



(c) (d)

Figure 1.13: Mounting PDA adapter to the wrist using 20 mm long screw

(a) (b)

Figure 1.14: Mounting PDA hand phantom to PDA hand adapter

(a) (b)

Figure 1.15: Fixing the PDA hand phantom by tightening 61 mm screws

elbow and wrist) to be freely rotated. Position the arm and hand to the desired posture and tighten the locking knob. Please use the wrist

to position the hand to prevent damage to the hand adapter.

1.5 Butt Phantom

(a) (b)

Figure 1.16: Buttocks phantom BUTT V5.1 (a) back view, (b) front view

The generic buttocks phantom BUTT-V5.x consists of an outer bulk part manufactured from a silicone- and carbon-based mixture (color: black) with an inner low-loss dielectric structure (fixed with minimal metallic parts). The material target parameters are based on the data given in CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.2.1 (March 2013). The BUTT-V5.x phantom has been developed for performance of EM evaluations in combination with theTORSO-X-V5.x phantom. It can be easily attached to the bottom plate of the torso phantom and complemented with the right and left generic leg phantoms (LEGR-V5.x and LEGL-V5.x).

1.5.1 Mounting the Buttocks

The following describes how the BUTT-V5.x phantom is mechanically attached to theTORSO-X-V5.x phantom. Installation requires one flathead screwdriver (size one).

(a) (b)

Figure 1.17: Mounting the BUTT-V5.x to the torso phantom

1. Place the torso and the buttocks phantoms in a horizontal position on a table. On the bottom plate of the torso phantom you will find four holes that align with holes on the buttocks phantom (see Figure 1.17 (a)); push the phantoms together such that the holes on the torso phantom overlap with those fo the buttocks phantom. Please be sure to align the two phantoms with front sides both facing front.

2. Use four the 8 mm long screws provided (two on each side) to attach the buttocks phantom to the torso phantom as demonstrated in Figure 1.17 (b).

The BUTT-V5.x phantom can sit self-supported on any flat surface. However, it is recommended to use the whole-body stand (STAND-V5.x) to support the phantom.

The following describes the handling of the bottom extended torso phantom together with the stand.

(a) (b) (c)

Figure 1.18: (a) Recommended grip to lift the phantom on the socle (red circle (b)) of the stand to support the phantom (c)

1. Two persons are needed to lift the phantom. Be aware that the torso together with the butt extension weighs ca. 50 kg. Figure 1.18 (a) shows the recommended grip: Lift the phantom by holding it on the silicone of the back part of the buttocks phantom. Use your second hand to support the torso at the shoulder.

2. The stand is equipped with a socle (see Figure 1.18 (b)) that perfectly fits the recess on the bottom of the buttocks phantom. Place the torso on the socle and ensure that it is fully engaged. The phantom is now completely supported by the stand (Figure 1.18 (c)).

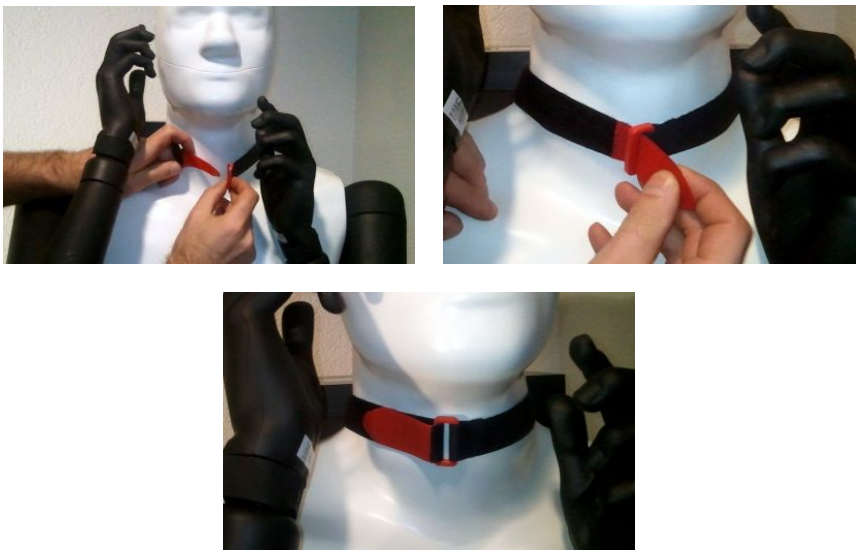


Figure 1.19: Tightening the safety belt around the phantoms neck

3. Please always tighten the safety belt around the neck of the phantom as shown in Figure 1.19.

1.6 Leg Phantom

The posable right and left legs LEGR-V5.x (LEG Right) and LEGL-V5.x (LEG Left) are posable generic thigh and shank phantoms consisting of an inner low-loss dielectric structure with knee joints. Both thigh and shank are covered with a bulk part manufactured from a silicone- and carbon-based mixture according material target parameters given in CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.2.1 (March 2013). With this architecture, the LEGR/L-V5.x is suitable for EM evaluations above 500 MHz. The LEGR/L-V5.x can be easily attached via the BUTT-V5.x phantom to the TORSO-X-V5.x phantom. With a foot phantom (JIAOR/L V5.x) attached at the ankle joint, a complete leg is formed.

1.6.1 Mounting the Leg

The following describes how the right and left leg phantoms are mechanically attached to the buttocks phantom. Installation requires one allen wrench 8 mm in size.

1. Before you start to mount the legs to the buttocks, we strongly recommend that the torso is pre-assembled with the buttocks phantom and

(a) (b) (c)

Figure 1.20: Locations of mounting holes and fixing screw to attach the legs to the buttocks phantom

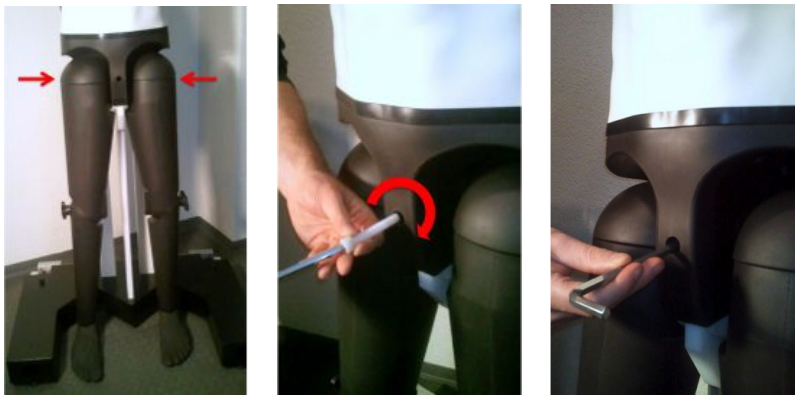
mounted on the stand support (STAND-V5.x) as described earlier in Section 1.5.1.

2. In Figure 1.20, the locations of the mounting holes for the left and right legs and the fixing screw position are shown. Ensure that the left and right legs are being attached to the correct sides of the buttocks phantom.

3. The legs should be attached in a straight configuration (if the legs are bent, loosen the knob (Figure1.21) and straighten them). It is important that the left leg (LEGL-V5.x) is mounted first.

Figure 1.21: The knob on the knee to adjust the leg position

Figure 1.22: Attaching the leg to the buttocks phantom. IMPORTANT: Left leg mounted first



(a) (b) (c)

Figure 1.23: (a) Pushing the legs from both sides, (b) and (c) inserting and tightening plastic screw to fix the legs to the buttocks

4. Insert the joint of the left leg into the corresponding mounting hole in the BUTT-V5.x phantom (Figure 1.22 top). Then insert the joint of the right leg into the right mounting hole (Figure 1.22 bottom). Note that the right joint is recessed in the joint of the left leg.

5. When both legs are in their corresponding mounting holes, push them from both sides simultaneously as shown in Figure 1.23 (a) until they click.

6. Insert the 60 mm plastic screw into the screw hole to fix the legs. Tighten the screw only hand-tight.

1.7 Foot Phantom

The right and left foot phantoms JIAOR-V5.x and JIAOL-V5.x are homogeneous anthropomorphically shaped foot phantoms manufactured from a silicone- and carbon-based mixture (color: black) and a low-loss dielectric insert at the heel. The material target parameters are based on the data given in CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.2.1 (March 2013). The JIAOR/L-V5.x phantom has been developed for EM evaluations and can be easily attached to the leg phantom (LEGR/L-V5.x) ankle joint to complete a posable human leg.

Figure 1.24: Mounting foot phantom

1.7.1 Mounting the Foot

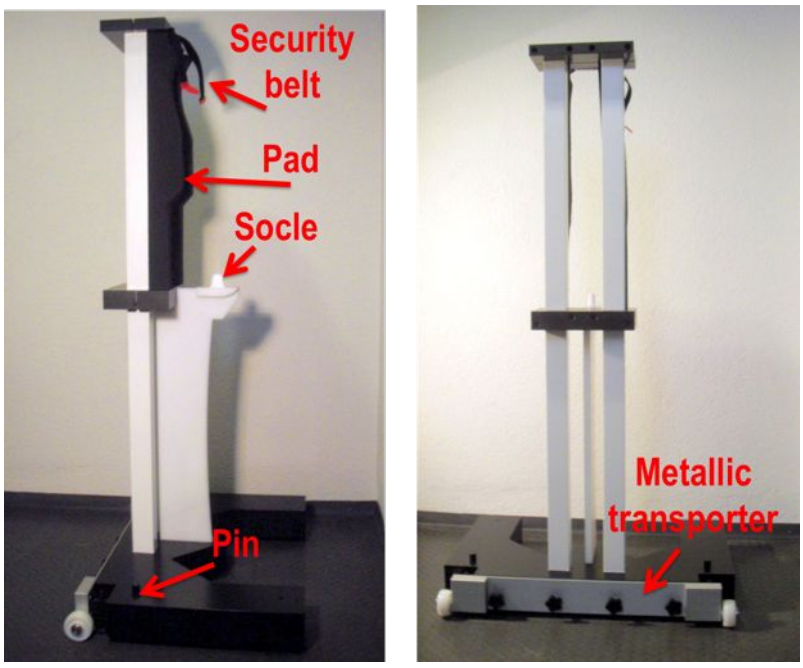
The installation of the JIAOR/L V5.x foot phantom does not require any special tools.

1. Ensure that the left and right feet are attached to the corresponding legs.

2. Attach the foot to the tip of the ankle as shown in Figure 1.24 and screw it in clockwise direction until it is tight.

1.8 Stand for Whole-Body Phantom w/ Wheels

The STAND-V5.x has been developed for the support and transport of the Whole-Body EM Phantom POPEYE V.5x. It consists of a wooden base with a detachable metallic transporter and a vertical support structure composed of white polyoxymethylene (POM), white glass-fiber-reinforced poles, and black glass-fiber-reinforced PA66 engineering plastic. The metallic transporter can be removed for EM evaluations.



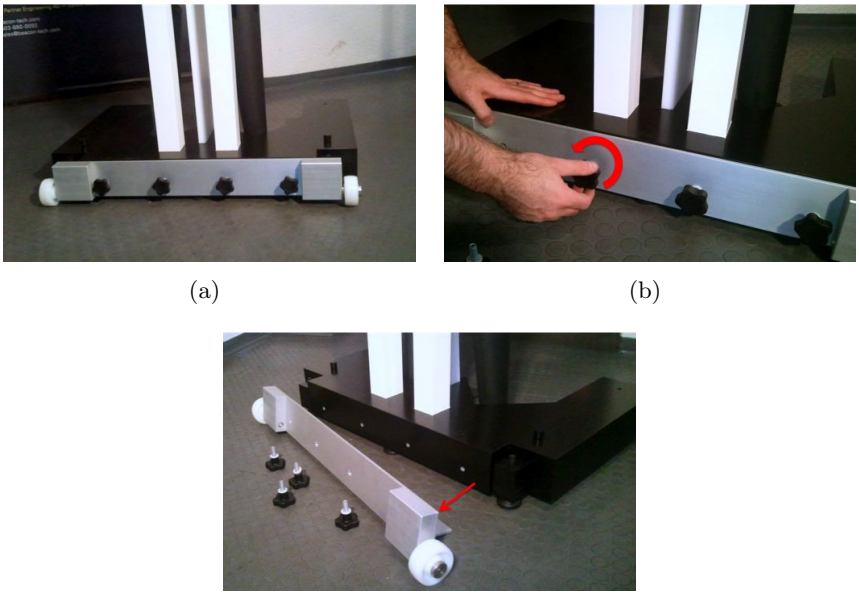
(a) (b)

Figure 1.25: STAND-V5.x parts

1.8.1 Operation

Support

The following describes how the STAND-V5.x is used in the support mode.

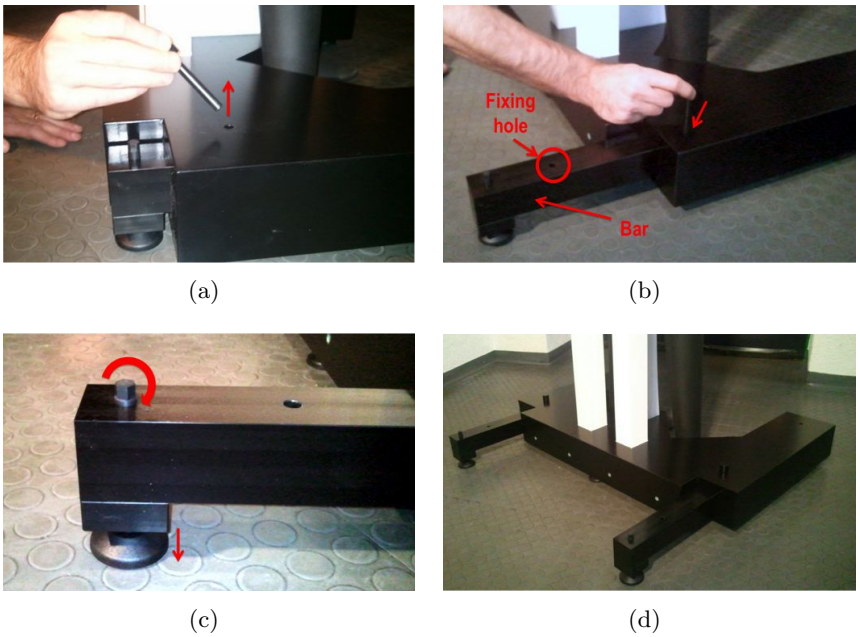


(a) (b)

(c)

Figure 1.26: Removing the metallic transporter for EM evaluations

1. Loosen all four screws on the bottom of the stand (Figure 1.26 (a) and (b)) and remove them.
2. Remove the entire metallic transporter from the stand as shown in Figure 1.26 (c). The stand is now completely metal free.
3. Pull out the two pins on each side as shown in Figure 1.27 (a).
4. Pull out the bar on each side and fix the position with the pin in one of the predetermined fixing holes (Figure 1.27 (b)).
5. Loose the screws to adjust the stand feet on the floor, then tighten again (Figure 1.27 (c) and (d)).



(a) (b)

(c) (d)

Figure 1.27: Stabilising the stand

Transport

The stand can also serve as a dolly for transporting the whole-body phantom (see Figure 1.28).

1. Stand behind the dolly (STAND-V5.x) and put your left (or right) foot on the wheel axle. Step back a foot or two with your right foot to lean the stand back to engage the wheels. Push and steer the stand with the whole-body phantom to your desired destination.

2. If you need to overcome an obstacle during transport ask a colleague to push and lift while you pull and steer the wheels of the dolly in the right direction.

Figure 1.28: STAND-V5.x used as a dolly to transport the whole-body phantom

1.9 Positioning POPEYE V5.x

The Whole-Body EM Phantom POPEYE V5.x can be positioned in any realistic human pose. Please follow the procedures recommended below for lifting the whole-body phantom documented (see Figure 1.29). Note that at least three people are needed to lift the whole phantom.

It is strongly recommended to ensure that the carrying path of the whole-body phantom is as short as possible.

1. Loosen the knobs on both legs.
2. Two people, one on each side of the phantom, hold the bottom grip with one hand and use the other hand to support the torso at the shoulder (see Figure 1.29 top). The third person lifts both legs simultaneously by holding them above and behind the knee joints.
3. Lift the whole-body phantom just high enough to remove it from the socle and carry it to the desired location (e.g., POPEYE V5.x sitting on a chair, Figure 1.29 bottom).
4. Pose the phantom by adjusting all joints, then tighten all knobs to fix.

Figure 1.29: Recommended procedure to lift the whole-body phantom. Bottom right: Position with laptop on a chair

1.10 Key Dimensions

Weight

TORSO-OTA-V5.x:	41.4 kg
ARMR-V5.x and ARML-V5.x:	7.2 kg
LEGR-V5.x and LEGL-V5.x :	27.2 kg
BUTT-V5.x:	5.3 kg
JIAOR-V5.x and JIAOL-V5.x:	2.8 kg
SHO-V2Rx and Lx (incl. adapter):	1.4 kg
TOTAL:	85.3 kg

TORSO-X-V5.x empty:	12.4 kg
STAND-V5.x:	46.5 kg

Dimensions

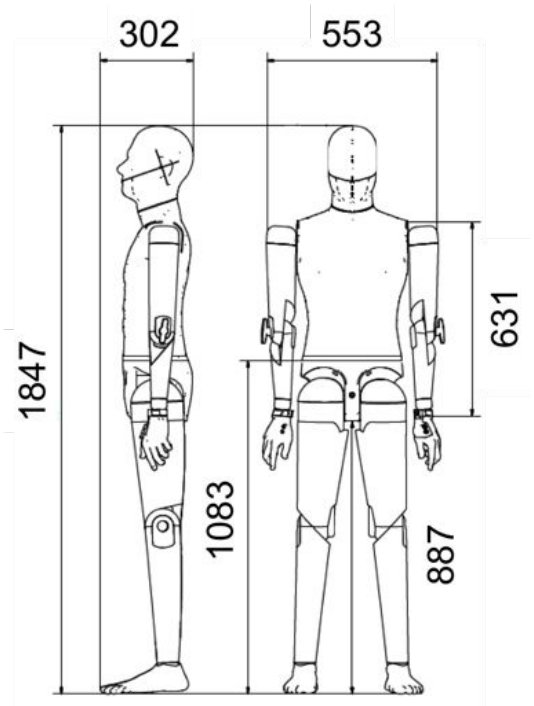


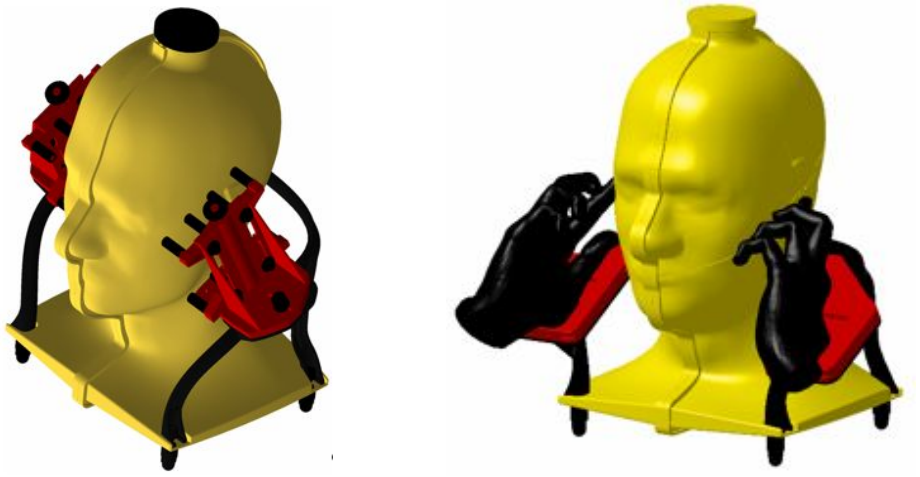
Figure 1.30: Dimensions of the Whole-Body EM Phantom POPEYE V5.x in mm

Chapter 2

SAM-V4.5BS Head Phantom (CTIA 3.x)

2.1 Introduction

SAM Head V4.5BS (Broadband Solid) has been designed for assessment of the radiation pattern or total radiated power. Its geometry complies with the SAM data as defined by IEEE SCC34 and 3GPP TR25.914 "Measurements of Radio Performances for UMTS Terminals in Speech Mode" Release 6, CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.x High precision casting ensures accurate shape, thickness and tolerances in the relevant areas.



(a) (b)

Figure 2.1: SAM Head V4.5BS (a) with device holder and (b) with hand fixture/positioner and hand phantoms

The head is available with two different types of integrated lightweight holders (device holder and hand fixture/positioner) allowing the precise positioning of devices in both touch and tilt positions, aligned to the engraved reference lines. It may be operated in any position when fixed with four screws at its base; the base flange serves simultaneously as a pedestal and interface for fixation on any support (a torso version and shoulder mountable flanges are not available).

2.2 Construction

The shell of SAM Head V4.5BS is manufactured from reinforced polypropylene and each head is individually pressure tested. Regarding shape and shell thickness, SAM-V4.5BS corresponds to SAM-V4.5CTIA but is filled with a broadband solid material (gel) with the dielectric specifications of head tissue from 300 MHz – 6 GHz according to the IEC 62209 and CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.x standards. Typical deviation of the used material with respect to the target dielectric head parameters is shown in the figure below. The dielectric properties have been measured and verified with both coaxial probe and coaxial TEM line.

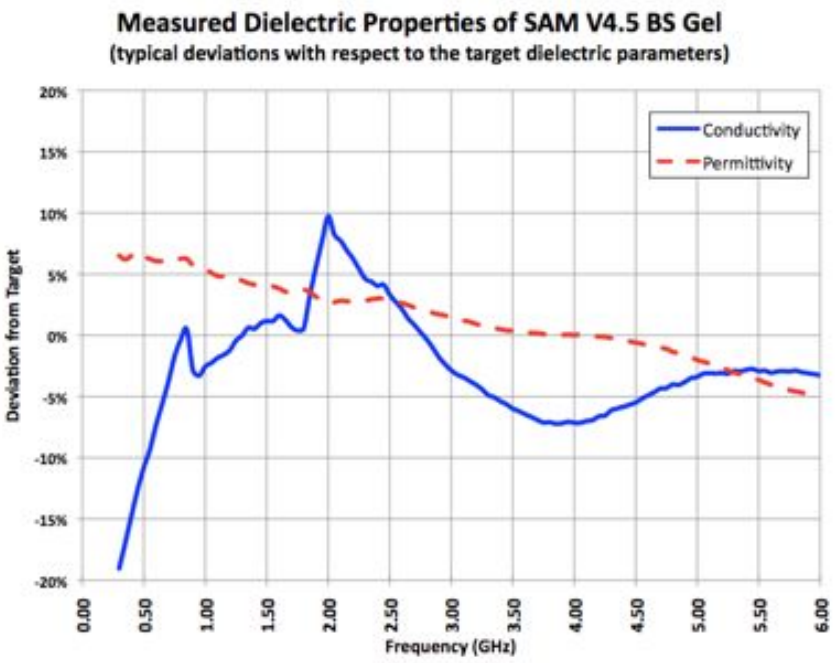


Figure 2.2: Typical deviation of the used material with respect to the target dielectric head parameters

The solid material does not separate and leak. It also reduces the weight of SAM-V4.5BS by more than 30% compared to the liquid sugar water solution (e.g., SAM-V4.5CTIA). The parameters of the gel are verified at 22.0°C. Maximum allowed operation temperature is 40.0°C. The head shall be stored at normal room temperature around 22°C. It must not be exposed to temperatures >30°C or <2°C or to sunlight radiation (heating up). If used according this instructions the head phantoms are compliant with CTIA OTA Test Plan V3.2 standards for three years, i.e., the measurement data given in the corresponding certificates shall be used as the basis for the uncertainty assessments.

2.3 Dimensions

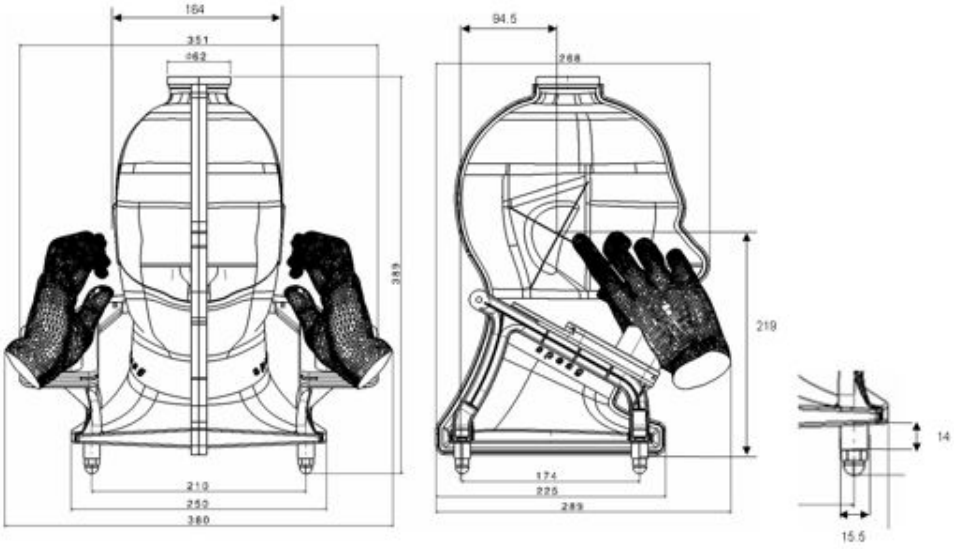


Figure 2.3: Dimensions of the head with hand fixture/positioner and hand phantoms (mm)

2.4 Operation

SAM Head V4.5BS can be used self-supported on its feet. Operation on a turntable or positioner is possible in any position, using the fixation at the four 8 mm through holes in the bottom flange with appropriate spacers.

It is strongly recommended not to remove the cap and/or ears because the shape of the head and the stability of the gel material may be altered.

Note: For safe transport of SAM-V4.5BS Head, it is strongly recommended to pack the head phantom in TCCT in an additional box with foam filling, e.g. in the TCCT Transportation Box as shown in Chapter 13.

2.5 Summary of Technical Specifications

SAM-V4.5BS Anthropomorphic Head Model

- Shape according to IEEE SCC34 and compatible to 3GPP and CTIA
- Parameters of filling solid material compatible (typ. ±10%) with head simulating media as defined by IEEE/IEC and CTIA standards over the entire frequency range (300MHz – 6GHz)
- Gel filling stable for 3 years if kept closed and in temperature range 22 ±5 °C
- Reduced weight by more than 30% compared to the sugar-water solution (e.g., SAM-V4.5CTIA)
- Easy and reproducible test device positioning for both touch and tilt positions
- Compatible with SPEAG device holders and hand fixture/positioners

Construction

- High precision injection molded PP
- Shell thickness 2 ±0.2 mm (6 mm at ear point)
- Integrated positioning lines
- Sealed top cap for use with 17 mm hexagonal key
- Filled with approximately 5.9 liters broadband solid material (gel like)

Application

Assessment of radiation pattern or of total radiated power.

Dimensions

Total height:	394 mm
Gel height:	292 mm
Width (head only):	250 mm
Width with device holder:	310 mm
Width with hand fixture:	351 mm
Depth:	269 mm
Base plate (l x b):	250 x 210 mm
Fixation raster:	210 x 174 mm

The base plate has 4 through holes for 8 mm fixation screws. The phantom is delivered with spacers and screws for self-supported operation on a table. It may be fixed to a positioner or turntable for operation in any position.

Weight

7.2 kg (excluding device holder and hand fixture) i.e. 30% lighter than phantoms filled with sugar based liquids.

Device Holder

- Integrated lightweight holder, accurate and easy to operate.
- Enables precise positioning in both touch and 15° tilted positions.
- 2 rows of 4 fingers are moved symmetrically to the ear-mouth line; this symmetrical positioning is retained during width adaptation. The fingers have lengths ranging from 26 – 31 mm.
- 2 sets of exchangeable sleeves are included for the fingers, with outer diameters of 12 mm and 18 mm.
- Tilting of the fixed device is possible within a range of ±20° (controllable by marks with 1° resolution at the outside of the holder).
- The maximum supported device width is 78 mm. The maximum distance between the first and last fixation points is 92 mm.

Hand Fixture/Positioner

- Integrated lightweight holder, accurate and easy to operate.
- Enables precise positioning of left or right hand phantom with device in a tilted position on the head phantom

- Enables horizontal and vertical adjustments of the mounted hand phantom
- Tilting of the mounted hand phantom is possible within a range of $\pm 11°$(controllable by marks with $1°$ resolution)

Chapter 3

SAM-V4.5BSE Head Phantom

3.1 Introduction

SAM-V4.5BSE (Ear) is a homogeneous anthropomorphically shaped head phantom with anatomically correct lossy ears with ear canal. It has been designed for assessment of the radiation pattern or total radiated power of devices such as hearing aids, wireless headphones and Bluetooth devices. Its geometry complies with the SAM data as defined by "Measurements of Radio Performances for UMTS Terminals in Speech Mode" Release 6 and CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.x. High precision casting ensures accurate shape, thickness and tolerances in the relevant areas.

Figure 3.1: SAM-V4.5BSE Head Phantom with anatomically correct lossy Ears with ear canal

The head may be operated in any position when fixed with four screws at its base; the base flange serves simultaneously as a pedestal and interface for fixation on any support (a torso version and shoulder mountable flanges are not available).

3.2 Construction

For the construction of the Head Phantom please refer to Chapter 2.2 on page 26.

The generic ears of the original SAM-V4.5BS head are replaced by the anatomically correct ear phantoms (left/right). The ear phantoms are manufactured from a silicon- and carbon-based mixture (color: black) with target parameters based on the hand data given in [1] to simulate cartilage composed tissues. The dielectric properties have been measured and verified with an open ended coaxial probe.

The parameters of the gel are verified at 22.0°C. Maximum allowed operation temperature is 40.0°C. The head shall be stored at room temperature around 22°C. It must not be exposed to temperatures >30°C or <2°C or to sunlight radiation (heating up). If used according this instructions the head phantoms are compliant with CTIA OTA Test Plan V3.x standards for three years, i.e., the measurement data given in the corresponding certificates shall be used as the basis for the uncertainty assessments.

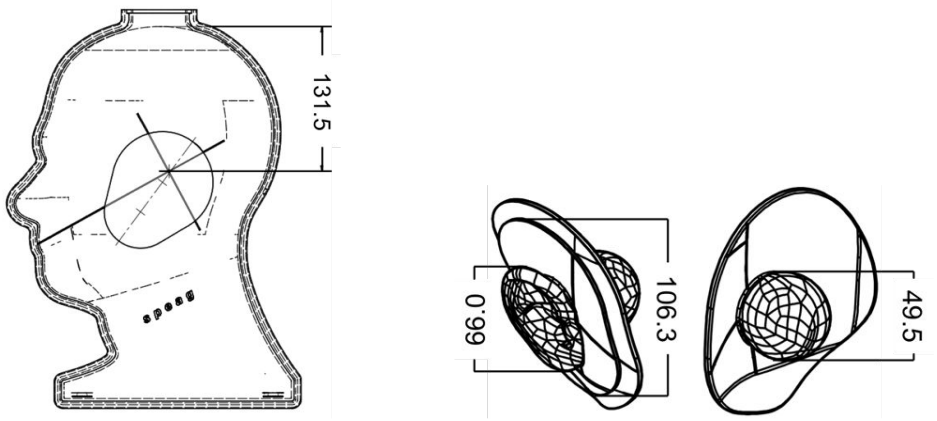
3.3 Dimensions

For the dimensions of the Head Phantom please refer to Chapter 2.3 on page 27.

Ear Phantom

The geometrical dimensions and orientation of the ear phantoms are illustrated in Figure 3.2 and listed in the table below together with the mechanical changes due to the ear integration. The ear phantom consists of a pinna, an ear canal and an inner part of the ear represented by a solid sphere (see Figure 3.2 (b)).

Width (head with ears):	281 mm
Pinna height:	66 mm
Inner sphere diameter:	49.5 mm
Ear canal length:	25 mm
Ear canal diameter:	7.8 mm
Weight (head with ears):	7.5 kg



(a) (b)

Figure 3.2: Position of the ear on the head (left) and ear dimensions (right) in mm

3.4 Operation

SAM-V4.5BSE Head Phantom can be used self-supported on its feet. Operation on a turntable or positioner is possible in any position, using the fixation at the four 8 mm through holes in the bottom flange with appropriate spacers. **It is strongly recommended not to remove the cap and/or ears because the shape of the head and the stability of the gel material may be altered.**

Note: For safe transport of SAM-V4.5BSE Head Phantom, it is strongly recommended to pack the head phantom in TCCT in an additional box with foam filling, e.g. in the TCCT Transportation Box as shown in Chapter 13.

3.5 Technical Specifications

- Head shape according to IEEE SCC34 and compatible to 3GPP and CTIA except area where ear phantoms are integrated
- Parameters of filling gel compatible (typ. ±20%) with head simulating media as defined by IEEE/IEC and CTIA standards over the entire frequency range (300MHz – 6GHz)
- Gel filling stable for 3 years If used according the instructions described above
- Dielectric parameters of the ear based on hand data parameters in [3]; relative permittivity and conductivity: within ±15% and ±20% of target parameters for 500 MHz – 3 GHz respectively

Chapter 4

SAM Head Phantom V4.5CTIA (CTIA 2.2)

4.1 Introduction

SAM Head V4.5CTIA has been designed for assessment of radiation patterns or total radiated power. Its geometry complies to the SAM data as defined by IEEE SCC 34, on which all relevant radiation standards are based. High precision casting ensures accurate shape, thickness and tolerances in the relevant areas. The integrated lightweight holder construction allows precise positioning of devices in both touch and tilt position, aligned to the engraved reference lines.

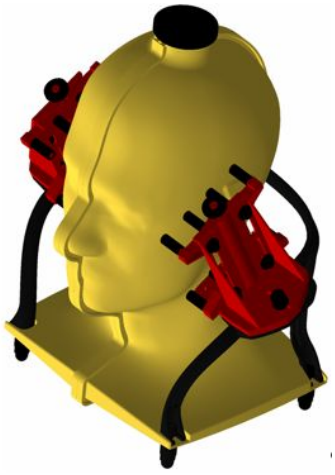


Figure 4.1: SAM Head V4.5CTIA with holder

SAM Head V4.5CTIA is manufactured from reinforced polypropylene and each head is individually pressure tested. Consequently, it has long-

term resistance to all current tissue simulating liquids and may be operated in any position when fixed with four screws at its basis. It is designed as a head with a short neck, without shoulders or torso. Its base flange serves simultaneously as pedestal and interface for fixation on any support. (A torso version and shoulder mountable flanges are not available.)

4.2 Dimensions

Height	
incl. cover and feet	394 mm
without cover	381 mm
Width	
Head only	250 mm
incl. holder	310 mm
Depth	269 mm
Fixation raster	
Width	210 mm
Depth	174 mm

4.3 Liquid Compatibility

The SAM Head V4.5CTIA has long-term compatibility to all currently available tissue simulating liquids (incl. DGBE recipes). When not put into use for extended periods of time, we recommend storing it empty after cleaning and rinsing with warm water.

The parameters of the liquid are verified at 22.0°C. The operation temperature is approximately 22°C ± 5°C in order to maintain measured liquid parameters. The head shall be stored at normal room temperature around 22°C. It must not be exposed to temperatures >35°C or <4°C or to sunlight radiation (heating up).

4.4 Caps for SAM Head Phantoms

Black Cap (Figure 4.2(a)):

The cap is manufactured of POM and consequently has long-term resistance to all current tissue simulating liquids including DGBE recipes.

Transparent Cap (Figure 4.2(b)):

The transparent cap is manufactured of PMMA and has long-term resistance to all current tissue simulating liquids excluding DGBE recipes. This cap has been designed to meet the CTIA guidelines “Test Plan for Mobile Station over the Air Performance, April 2005”. It allows assessing enclosed air that

might increase the uncertainty of compliance testing when used horizontally. The solution does not only enable careful examination of the amount of the enclosed air, but also its complete elimination with easy measures (see Section 4.5).

(a) (b)

Figure 4.2: (a) Black cap and (b) Transparent cap

4.5 Operation

SAM Head V4.5CTIA can be used self-supported on its feet. Operation on a turntable or positioner is possible in any position, using the fixation at the four 8 mm through holes in the bottom flange with appropriate spacers. Its sealing ensures leak-proof operation when filled with tissue simulating liquid in any position.

With black cap:

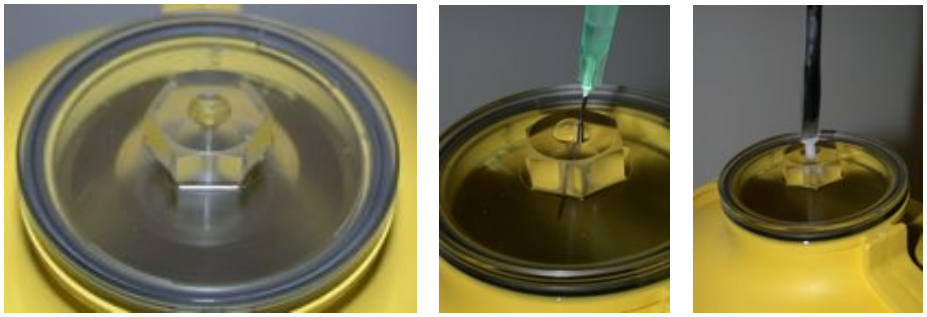
For operation with the head axis in horizontal position, possible enclosed air bubbles can be brought and kept in the shoulder flange region by flipping the head upside down before operation.

With transparent cap:

The air bubbles are accumulated at the top (carefully shake the head). The amount of enclosed air can be seen and measured through the cap (Figure 4.3(a)). In order to remove the bubbles, follow the procedure below:

1. Remove the screw in the center of the cap.
2. Add liquid with a syringe (Figure 4.3(b)).
3. Close the hole with the screw (Figure 4.3(c)).

This procedure can be repeated as often as needed.



(a) (b) (c)

Figure 4.3: Procedure to remove the air bubbles

4.6 Device Holder for SAM Head Phantoms

The SAM Head Phantom V4.5CTIA is available with an integrated lightweight device holder, which is accurate and easy to operate. It enables a precise positioning of the device on both head sides with high repeatability. The holder supports simulation of the hands-free condition but also allows use of a generic hand.

The holder consists of 2 rows of 4 fingers which are kept symmetrical to the ear-mouth line even if the width is adapted to the phone fixating the screw. The fingers have a length of 26 to 31 mm.

2 sets of foam sleeves are included, with outer diameter 12 mm and 18 mm. These sleeves give full flexibility for adapting all types of test device geometries by exchanging / removing / combining or shifting towards the head. Maximum supported device width is 78 mm. Distance between extreme first and last fixation finger is 92 mm.

Tilting of the fixed device is possible in a range ±20°, controllable by marks with 1° resolution at the outside.

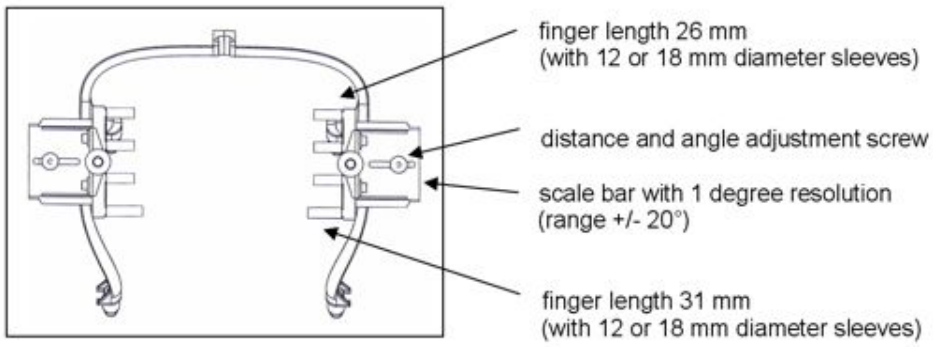

finger length 26 mm
(with 12 or 18 mm diameter sleeves)
distance and angle adjustment screw
scale bar with 1 degree resolution
(range +/- 20°)
finger length 31 mm
(with 12 or 18 mm diameter sleeves)

Figure 4.4: Lightweight device holder (view from top)

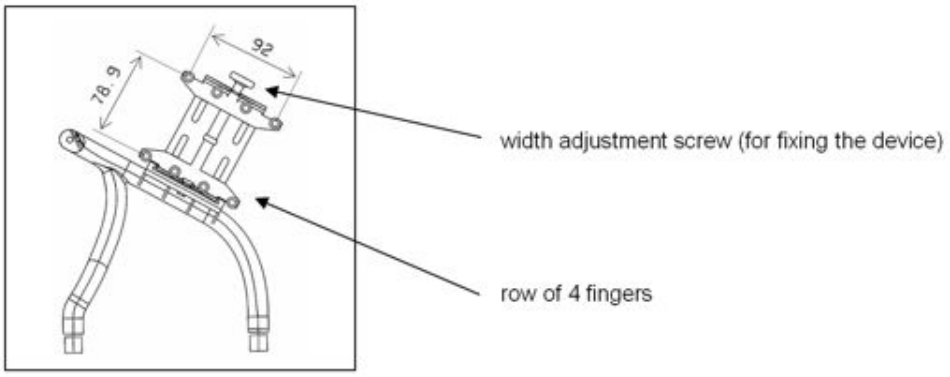


Figure 4.5: Lightweight device holder (view from head)

Note: For safe transport of SAM-V4.5CTIA Head, it is strongly recommended to remove the liquid from the head phantom and then pack it in TCCT in an additional box with foam filling, e.g. in the TCCT Transportation Box as shown in Chapter 13.

4.7 Summary of Technical Specifications

SAM-V4.5CTIA Anthropomorphic Head Model with device holder

- Shape according to IEEE SCC34
- Compatible with all common tissue simulating liquids (incl. DGBE recipes)
- Precise control of the size of air bubbles in the liquid with transparent cap
- Easy and reproducible test device positioning for both touch and 15° tilt position

Construction

- High precision injection molded PP
- Shell thickness 2±0.2 mm (6 mm at ear point)
- Integrated positioning lines
- Sealed top cap for use with 17 mm hexagonal key
- Filling volume approx. 5.9 liters
- Compatible with all head tissue simulating liquids (incl. DGBE type)

Application

Assessment of radiation pattern or of total radiated power.

Dimensions

Height:	394 mm
Width (head only):	250 mm
Width with holder:	310 mm
Depth:	269 mm
Base plate (l x b):	250 x 210 mm
Fixation raster:	210 x 174 mm

The base plate has 4 through holes for 8 mm fixation screws. It is delivered with spacers and screws for self supporting operation on a table. It may be fixed to a positioner or turntable using spacers and screws for operation in any position.

Weight

The empty weight without holder is 2.3 kg. Filled with 5.9 l of simulating liquid, the total weight will therefore be between 8.4 and 10.5 kg, depending on the liquid's density.

Device Holder

- Integrated lightweight holder, accurate and easy to operate.
- Enables precise positioning in both touch and 15° tilted position.
- 2 rows of 4 fingers are moved symmetrically to the ear-mouth line also if the width is adapted to the phone fixating the screw. The Fingers have a length of 26 mm (front one 31 mm).
- 2 sets of exchangeable sleeves are included, with outer diameter 12 mm and 18 mm.
- Tilting of the fixed device is possible in a range ±20° (controllable by marks with 1° resolution at the outside).
- Maximum device width is 78 mm. Distance between extreme first and last fixation point is 92 mm.

Chapter 5

SAM Hand OTA Phantom SHO-V2RB/LB (for Brick-shaped Phones)

5.1 Introduction

The SHO-V2RB and SHO-V2LB (right and left hand phantoms) are homogeneous anthropomorphically shaped hand phantoms for SPEAG SAM Head V4.5/CTIA/BS. They provide accurate radiation pattern or total radiated power testing of brick-shaped mobile phones. Thoroughly designed fixture/positioners, spacers and measurement tools are available to enable precise and repeatable positioning of the device in the hand. The hand phantoms, spacers and other accessories are compliant with the CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.x.

5.2 Construction

The SHO-V2 hand phantoms are manufactured from a silicon- and carbon-based mixture (color: black). The hand target parameters based on real hand measurements and parameters are compliant with CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.x. The hand is sufficiently flexible to grip the range of device sizes and sufficiently stiff to remain in consistent grip. The spacer is manufactured from a low loss and RF transparent hollow material with a wall thickness less than 2 mm. The measurement scale on the spacer is made of a low volume, low loss solid material.

(a) (b)

(c)

Figure 5.1: (a) SHO-V2RB, (b) SHO-V2LB and (b) SAM-V4.5BS with hand phantom and positioner

5.3 Dimensions of Hand Phantom and Spacer

Geometry

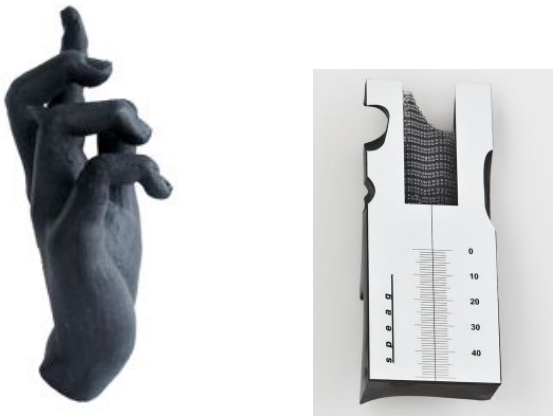
Grip and dimensions are according to human factor studies and hand anthropometric research. They are compliant with CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.x.

Hand

Height	205 mm
Wrist width	61 mm
Hand width	97 mm

Spacer

Height	120 mm
Width	48 mm



(a) (b)

Figure 5.2: (a) SHO-V2RB Hand phantom and (b) its spacer

5.4 Hand Phantom Fixture/Positioner

SHO-V2 is available with an integrated lightweight high precision fixture/positioner which is fully compatible with the SAM-V4.5/CTIA/BS. It enables precise positioning of a left or right hand phantom with the device in a tilted position on either sides of the head phantom with high repeatability.

The fixture/positioner consists of three parts which allow the user to perform rotation and movements of the hand with DUT (Device Under Test) (Figure 5.3). Tilting of the mounted hand phantom is possible within a range of $\pm 11^\circ$ (controllable by marks with 1° resolution).

The DUT and hand positioning procedure is defined below.

5.5 Alignment Tool B

The alignment tool is used to measure the reference position of the bottom of the DUT with arbitrary chin curvature so that the user can align the ring fingertip with the bottom of the DUT consistently.

The tool consists of a flat slab with a raised guiding strip along one side. The guiding strip has a 60° angled corner at the bottom which enables to obtain the desired amount of contact according to human factor studies. The scale on the tool agrees with the scale on the hand phantom spacer.

5.6 Recommended Operation

The DUT positioning is performed in two steps. The recommended procedure is to first place the DUT into the grip of the hand phantom, and then to position this assembly against the SAM-V4.5/CTIA/BS head phantom.

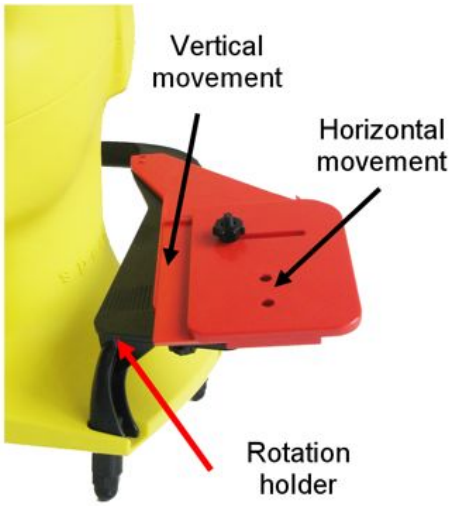


Figure 5.3: Hand phantom fixture/positioner

Positioning DUT relative to the hand phantom

Device positioning with respect to the hand phantom is performed using the hand phantom spacer and the alignment tool B.

1. Place the DUT on the alignment tool B and fit it into the corner between the slab and the guiding strip. Slide the DUT down until it reaches the angled corner.

2. Record the chin length from the scale on the alignment tool (Figure 5.5(a)). If the DUT length measured using the side ruler is more than 120 mm then the additional length beyond 120 mm should be added to the chin length recorded.

3. Place the DUT on the spacer and between the fingers of the hand phantom. The bottom of the DUT should align with the chin length recorded in step 2 (Figure 5.5(b)). The vertical centerline of the DUT should be centered with the spacer.

4. While keeping the DUT in the position defined in the previous steps, make sure that the index finger is in good contact with the DUT (Figure 5.5(c)). We recommend using short (∼1.5 cm) "3M Dual-Lock" strip provided with the hand phantom to fix the DUT to the hand phantom.

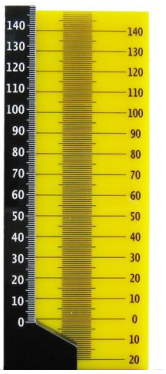


Figure 5.4: Alignment tool B

(a) (b) (c)

Figure 5.5: Positioning DUT relative to the hand phantom

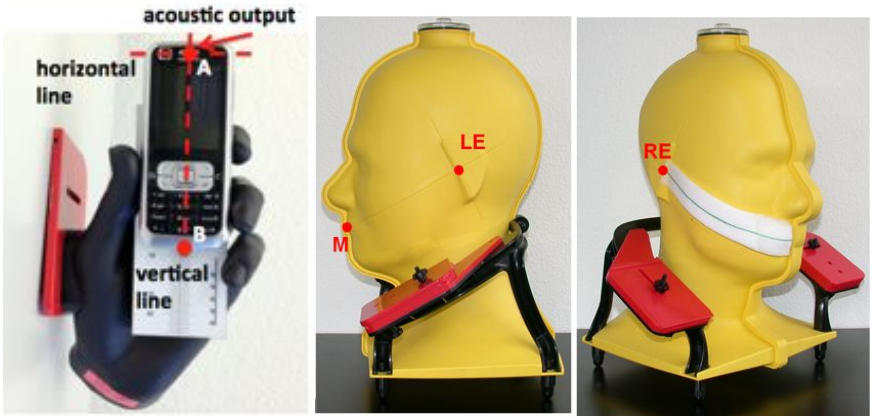
Positioning DUT and hand phantom relative to the head phantom

Once the DUT is positioned on the hand phantom, the DUT and the hand phantom (DUT/Hand) will be placed in a tilted position (cheek + 6°) on the head phantom.

1. Define two imaginary lines on the front side of the DUT as shown in Figure 5.6(a). The vertical line passes through the midpoint of the width of the DUT at the level of acoustic output (point A) to the midpoint of the width at the bottom of the DUT (point B). The horizontal line is perpendicular to the vertical line and intersects with the vertical line at point A.

2. The locations of the left ear (LE), right ear (RE) and mouth (M) points on the SAM-V4.5/CTIA/BS head phantom are shown in Figure 5.6(b). Mount Mask6 on the head phantom (Figure 5.6(c)). We recommend

using two small pieces of double-sided tape at the center and at the mouth locations of the mask to mount it to the head phantom.



(a) (b) (c)

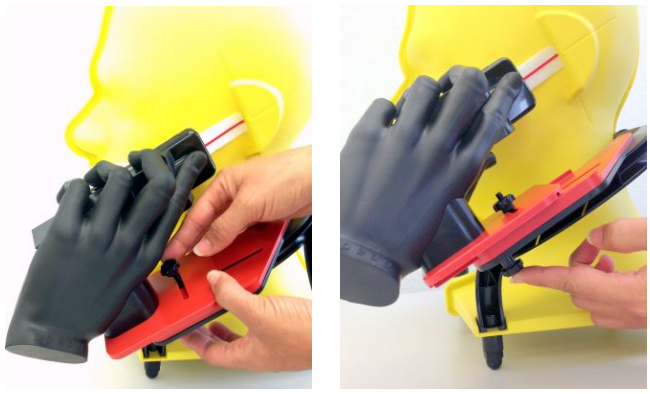
Figure 5.6: (a) Vertical and horizontal reference lines, (b) mouth and ear locations on head phantom, (c) Mask6 mounted on head phantom

3. Place DUT/Hand on the fixture/positioner and fix them using the screw (Figure 5.7(a)).

4. Using the vertical movement part of the fixture/positioner, move the DUT close to the surface of the SAM head phantom such that point A is on the (virtual) extension of the line passing through points RE and LE on the head phantom (Figure 5.8(a)).

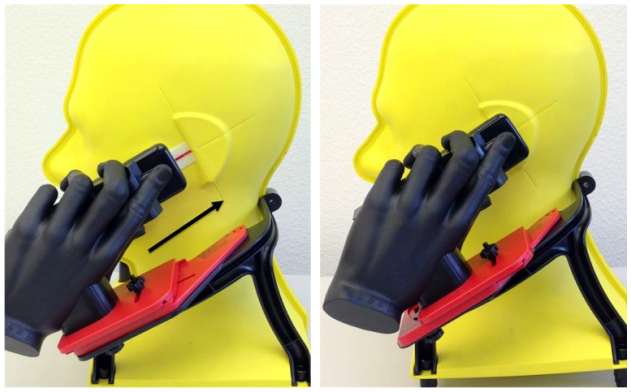
5. Use the horizontal movement part to translate the DUT/Hand towards the head phantom along the line passing through RE and LE until the DUT touches the ear (Figure 5.8(b)). Fix upper parts using the screw at the top of the fixture/positioner.

6. Loosen the screw below the fixture/positioner (Figure 5.7(b)) and rotate DUT/Hand until any point on the DUT or hand phantom is in contact with the SAM-V4.5/CTIA/BS or SAM Mask6 spacer at a point below the ear (Figure 5.8(c)).

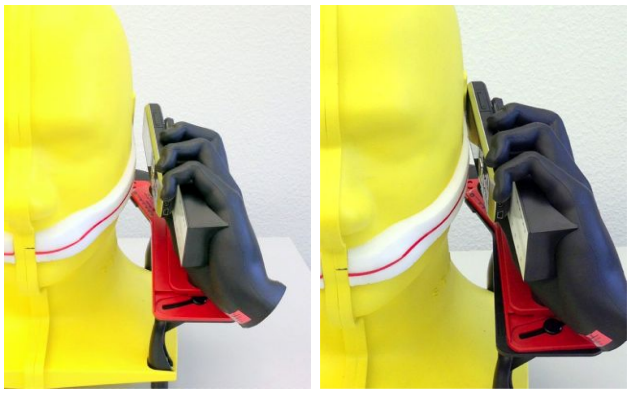


(a) (b)

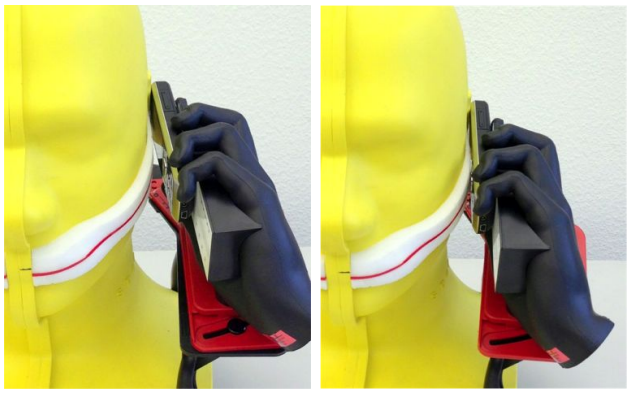
Figure 5.7: (a) Mounting the hand on the fixture/positioner using the screw at top; (b) loosening the screw at the bottom to rotate it



(a)



(b)



(c)

Figure 5.8: Positioning hand phantom with DUT relative to head phantom

Chapter 6

SAM Hand OTA Phantom SHO-V2RC/LC (for Clam-shell Phones)

6.1 Introduction

The SHO-V2RC and SHO-V2LC (right and left hand phantoms) are homogeneous anthropomorphically shaped hand phantoms for SPEAG SAM Head V4.5/CTIA/BS. They provide accurate radiation pattern or total radiated power testing of clam-shell (fold) mobile phones. Thoroughly designed fixture/positioners, spacers and measurement tools are available to enable precise and repeatable positioning of the device in the hand. The hand phantoms, spacers and other accessories are compliant with the CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.x.

(a) (b)

Figure 6.1: (a) SHO-V2RC and (b) SHO-V2LC

6.2 Construction

The SHO-V2 hand phantoms are manufactured from a silicon- and carbon-based mixture (color: black). The hand target parameters based on real hand measurements and parameters are compliant CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.x. The hand is sufficiently flexible to grip the range of device sizes and sufficiently stiff to remain in consistent grip. The spacer is manufactured from a low loss and RF transparent hollow material with a wall thickness less than 2 mm. The measurement scale on the spacer is made of a low volume, low loss solid material.

6.3 Dimensions of Hand Phantom and Spacer

Geometry

Grip and dimensions are according to human factor studies and hand anthropometric research. They are compliant with CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.x.

Hand

Height	188 mm
Wrist width	61 mm
Hand width	97 mm

Spacer

Height	104 mm
Width	44 mm

(a) (b)

Figure 6.2: (a) SHO-V2RC Hand phantom and (b) its spacer

6.4 Hand Phantom Fixture/Positioner

SHO-V2 is available with an integrated lightweight high precision fixture /positioner which is fully compatible with the SAM-V4.5/CTIA/BS. It enables precise positioning of a left or right hand phantom with the device in a tilted position on either sides of the head phantom with high repeatability.

The fixture/positioner consists of four parts which allow the user to perform two different rotations and movements of the hand with DUT (Device Under Test) (Figure 6.3 - top part integrated to hand phantom is not shown in the figure). Tilting of the mounted hand phantom is possible within a range of ±11° (controllable by marks with 1° resolution).

The DUT and hand positioning procedure is defined below.

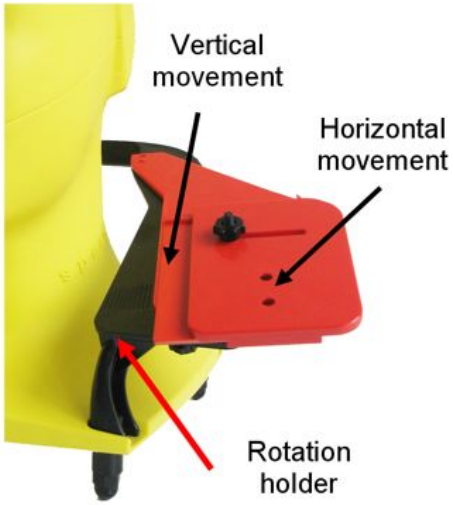


Figure 6.3: Hand phantom fixture/positioner

6.5 Alignment Tool C

The alignment tool is used to measure the reference position of the bottom of the DUT so that the user can achieve consistent and repeatable positioning of the DUT in the hand. Alignment Tool C has two rounded humps which represents the index fingertip of the hand and the palm spacer on which the DUT is placed. It allows the user to make sure that the index finger remains in contact with the flip of any DUT geometry. The line marking along its side wall helps aligning the DUT hinge axis of rotation. The scale for measuring the bottom of the DUT is split up in order to minimize parallax discrepancies when measuring the DUT (see below).

The scale on the tool agrees with the scale on the hand phantom spacer.

Figure 6.4: Alignment tool C

6.6 Recommended Operation

The DUT positioning is performed in two steps. The recommended procedure is to first place the DUT into the grip of the hand phantom, and then to position this assembly against the SAM-V4.5/CTIA/BS head phantom.

Positioning DUT relative to the hand phantom

Device positioning with respect to the hand phantom is performed using the hand phantom spacer and the alignment tool C.

1. Open the DUT and place it face-up on the alignment tool C as shown in Figure 6.5(a). The side of the DUT should be aligned against the side wall of the tool.

2. There is a line engraved on the tool. The axis of the hinge of the DUT should be lined up to this marking on the tool. When this is done, the chin ruler on the tool will give the correct longitudinal position for placing the fold DUT into the hand phantom, with respect to the chin ruler on the palm spacer. The index finger must contact the flip of the DUT. Measure and record the bottom of the DUT by reading off the bottom ruler of the tool. Visually align the two halves of the split-level ruler to minimize parallax reading error.

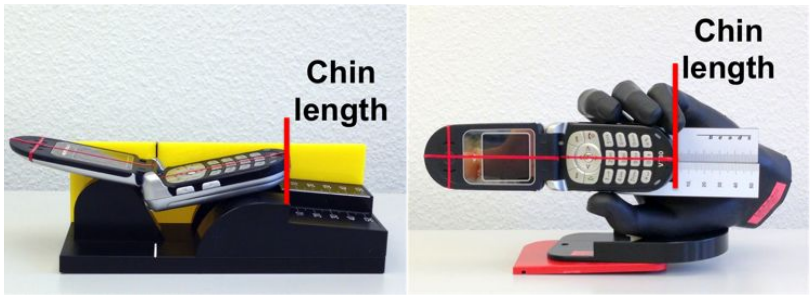
   (a) If the fold DUT has an obstruction near the back of its hinge that prevents the index finger from contacting the flip when the hinge is aligned to the engraved marking on the tool, then the index finger contact will be given higher priority. The DUT should be positioned in the tool so that the hinge is as close as possible to the marking, without raising the flip off of the rounded protrusion. The chin reading in this position will then be used to place the DUT in the hand phantom.

(b) If the DUT is an open slider or rotator then slide the DUT longitudinally until the base part of the DUT touches the narrow hump of the tool

3. Place the DUT on the index fingertip and palm spacer and between the fingers of the hand phantom. The bottom of the DUT should align with the chin length reading determined from step 2 on the spacer. Note that when reading the scale on the palm spacer and the alignment tool C, rulings on both sides of the step must be visually aligned to avoid parallax reading errors.

4. Move the DUT horizontally to align vertical centerline of the DUT with the center line of the spacer.

5. While keeping the DUT in the position defined in the previous steps, make sure that the index finger is in good contact with the DUT. We recommend using short (∼1.5 cm) "3M Dual-Lock" strip provided with the hand phantom to fix the DUT to the hand phantom.



(a) (b)

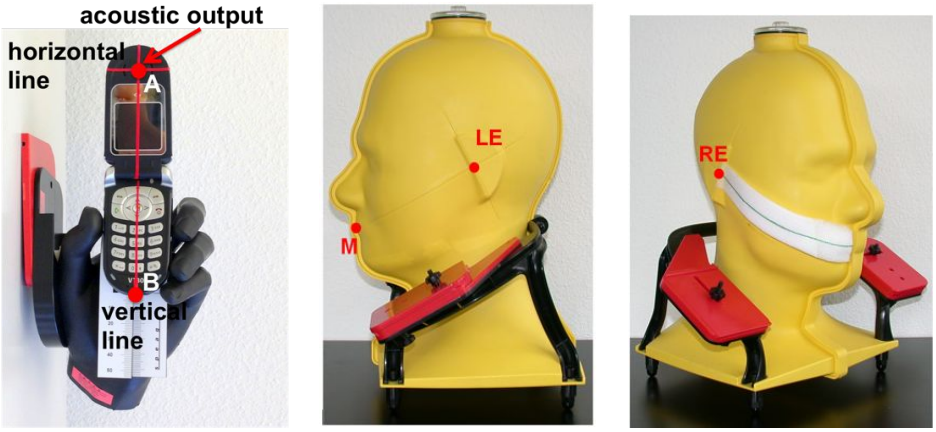
Figure 6.5: Positioning DUT relative to the hand phantom

Positioning DUT and hand phantom relative to the head phantom

Once the DUT is positioned on the hand phantom, the DUT and the hand phantom (DUT/Hand) will be placed in a tilted position (cheek + 6°) on the head phantom.

1. Define two imaginary lines on the front side of the DUT as shown in Figure 6.6(a). The vertical line passes through the midpoint of the width of the DUT at the level of acoustic output (point A) to the midpoint of the width at the bottom of the DUT (point B). The horizontal line is perpendicular to the vertical line and intersects with the vertical line at point A.

2. The locations of the left ear (LE), right ear (RE) and mouth (M) points on the SAM-V4.5/CTIA/BS head phantom are shown in Figure 6.6(b). Mount Mask6 on the head phantom (Figure 6.6(c)). We recommend using two small pieces of double-sided tape at the center and at the mouth locations of the mask to mount it to the head phantom.



(a) (b) (c)

Figure 6.6: (a) Vertical and horizontal reference lines, (b) mouth and ear locations on head phantom, (c) Mask6 mounted on head phantom

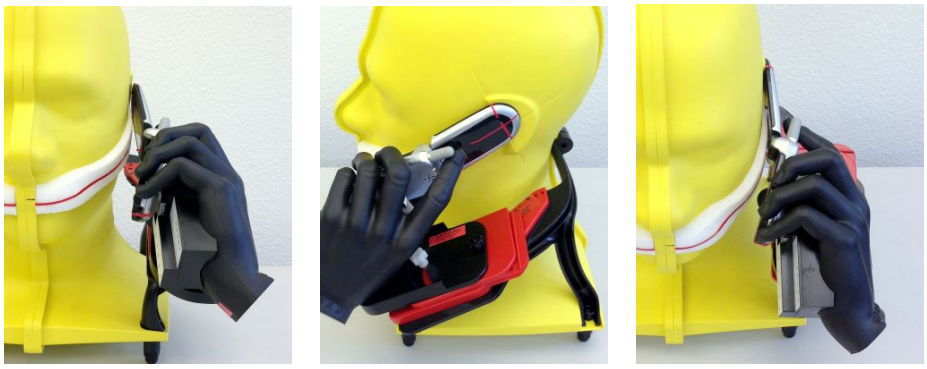
3. Place DUT/Hand on the fixture/positioner and fix them using the screws (Figure 6.7(a)).

4. Using the fixture/positioner, move the DUT/Hand towards the head phantom along the line passing through RE and LE until the DUT (point A) touches the ear (point RE). Fix upper parts using the screws at the top of the fixture/positioner.

5. Loosen the screw below the fixture/positioner (Figure 6.7(b)) and rotate DUT/ Hand until any point on the DUT or hand phantom is in contact with the SAM-V4.5/CTIA/BS or SAM Mask6 spacer at a point below the ear. Fix the screw.

(a) (b)

Figure 6.7: (a) Mounting the hand on the fixture/positioner using the screw at top; (b) loosening the screw at the bottom to rotate it



(a) (b) (c)

Figure 6.8: Positioning hand phantom with DUT relative to head phantom

Chapter 7

SAM Hand OTA Phantom SHO-V2RP/LP (for PDA (Wide) Phones)

7.1 Introduction

The SHO-V2RP and SHO-V2LP (right and left hand phantoms) are homogeneous anthropomorphically shaped hand phantoms suitable for use with PDA (Personal Digital Assistant – Wide) mobile phones for head and hand (talk mode) testing or hand only (data mode) testing. They provide accurate radiation pattern or total radiated power testing of PDA mobile phones. Thoroughly designed fixture/positioners and spacers are available to enable precise and repeatable positioning of the device in the hand. The hand phantoms, spacers and other accessories are compliant with the CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.x.

(a) (b)

Figure 7.1: (a) SHO-V2RP and (b) SHO-V2LP

7.2 Construction

The SHO-V2 hand phantoms are manufactured from a silicon- and carbon-based mixture (color: black). The hand target parameters based on real hand measurements and parameters are compliant with CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.x. The hand is sufficiently flexible to grip the range of device sizes and sufficiently stiff to remain in consistent grip. The spacer is manufactured from a low loss and RF transparent hollow material with a wall thickness less than 2 mm. The white cover on the spacer is made of a low volume, low loss solid material.

7.3 Dimensions of Hand Phantom and Spacer

Geometry

Grip and dimensions are according to human factor studies and hand anthropometric research. They are compliant with CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.x.

Hand

Height	180 mm
Wrist width	61 mm
Hand width	97 mm

Spacer

Height	135 mm
Width	56 mm

(a) (b)

Figure 7.2: (a) SHO-V2RP Hand phantom and (b) its spacer

7.4 Talk Mode

7.4.1 Hand Phantom Fixture/Positioner – Talk Mode

SHO-V2 is available with an integrated lightweight high precision fixture/ positioner which is fully compatible with the SAM-V4.5/CTIA/BS. It enables precise positioning of a left or right hand phantom with the device in a tilted position on either sides of the head phantom with high repeatability.

The fixture/positioner consists of three parts which allow the user to perform rotation and movement of the hand with DUT (Device Under Test) (Figure 7.3). Tilting of the mounted hand phantom is possible within a range of ±11°(controllable by marks with 1° resolution).

The DUT and hand positioning procedure is defined below.

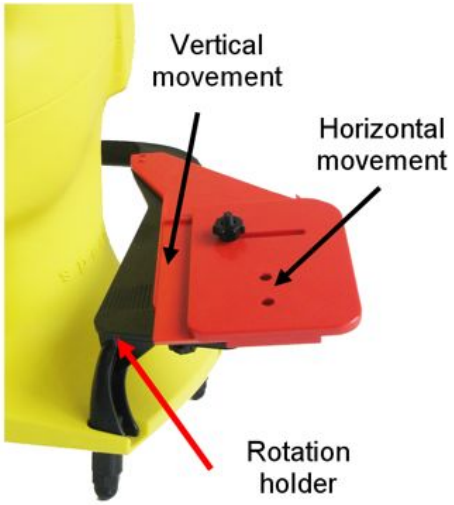


Figure 7.3: Hand phantom fixture/positioner – Talk Mode

7.4.2 Recommended Operation – Talk Mode

The DUT positioning is performed in two steps. The recommended procedure is to first place the DUT into the grip of the hand phantom, and then to position this assembly against the SAM-V4.5/CTIA/BS head phantom.

Adjusting hand phantom height

The position of the hand phantom on the horizontal movement part of the fixture should be adjusted in order to align the vertical line of the DUT to the line passing through points RE and M on the head phantom (Figure 7.6).

1. Measure width (w) of the DUT in mm. The required height adjustment is calculated with: h = (72 − w) /2
2. Choose a combination of spacer plates provided with the hand phantom (Figure 7.4(a): 1 mm, 2x2 mm, 4 mm) to achieve the required h value calculated in Step 1. For example, a DUT with a width of 66 mm will require the use of 1 mm and 2 mm spacer plates to accommodate the h value of 3 mm.
3. Loosen the screws connecting the fixture part to the hand cushion (Figure 7.4(b)). Insert spacer plates between the fixture and the hand cushion as shown in Figure 7.4(c).
4. Re-secure the fixture and hand cushion using the screws.

(a) (b) (c)

Figure 7.4: Adjusting hand phantom height: (a) set of spacer plates, (b),(c) inserting spacer plates

Positioning DUT relative to the hand phantom

Device positioning with respect to the hand phantom is performed using the hand phantom spacer and no alignment tool is required.

1. Place the DUT on the spacer and between the fingers of the hand phantom. Align the side of the DUT to the side wall of the spacer.
2. If the DUT is shorter than 135 mm, then align the top of the DUT to the top of the spacer. Otherwise, align the bottom of the DUT to the bottom wall of the spacer (Figure 7.5). We recommend using short (∼1.5 cm) “3M Dual-Lock” strip provided with the hand phantom to fix the DUT to the hand phantom.

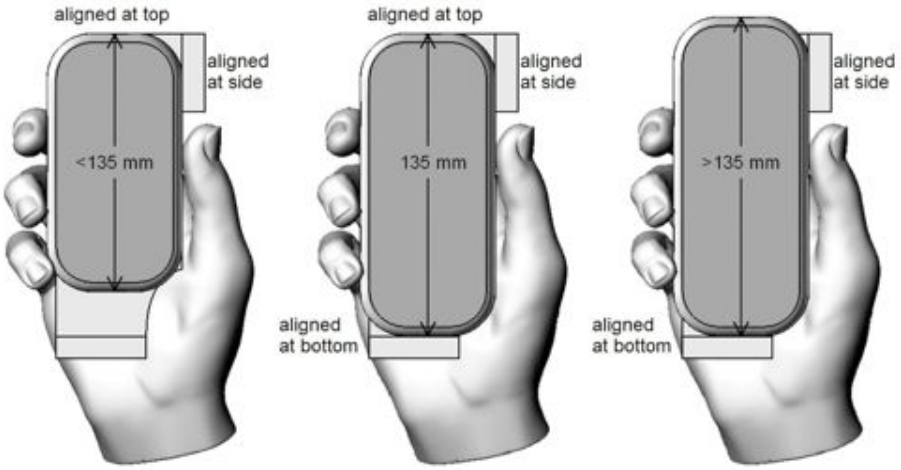


Figure 7.5: Positioning DUT relative to the hand phantom (source: CTIA OTA Test Plan V3.1 [January 2011])

Positioning DUT and hand phantom relative to the head phantom

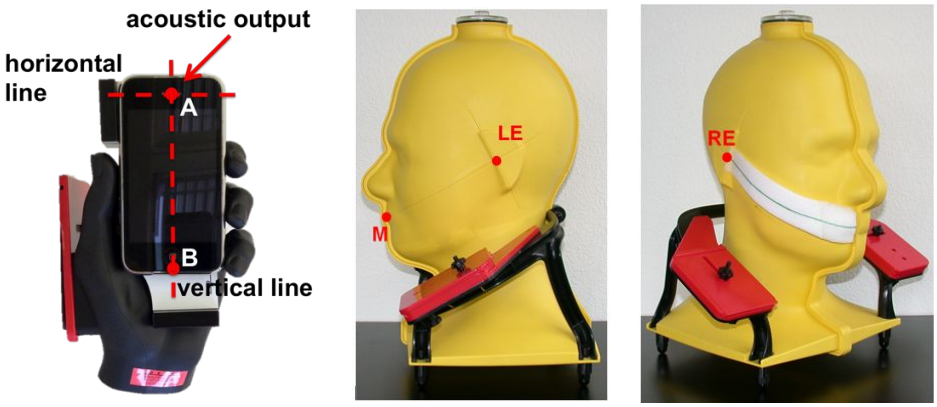
Once the DUT is positioned on the hand phantom, the DUT and the hand phantom (DUT/Hand) will be placed in a tilted position (cheek + 6°) on the head phantom

1. Define two imaginary lines on the front side of the DUT as shown in Figure 7.6(a). The vertical line passes through the midpoint of the width of the DUT at the level of acoustic output (point A) to the midpoint of the width at the bottom of the DUT (point B). The horizontal line is perpendicular to the vertical line and intersects with the vertical line at point A.

2. The locations of the left ear (LE), right ear (RE) and mouth (M) points on the SAM-V4.5/CTIA/BS head phantom are shown in Figure 7.6(b). Mount Mask6 on the head phantom (Figure 7.6(c)). We recommend using two small pieces of double-sided tape at the center and at the mouth locations of the mask to mount it to the head phantom.

3. Place DUT/Hand on the fixture/positioner and fix them using the screw (Figure 7.7(a)).

4. Using the vertical movement part of the fixture/positioner, move the DUT close to the surface of the SAM head phantom such that point A is on the (virtual) extension of the line passing through points RE and LE on the head phantom (Figure 7.8(a)).



(a) (b) (c)

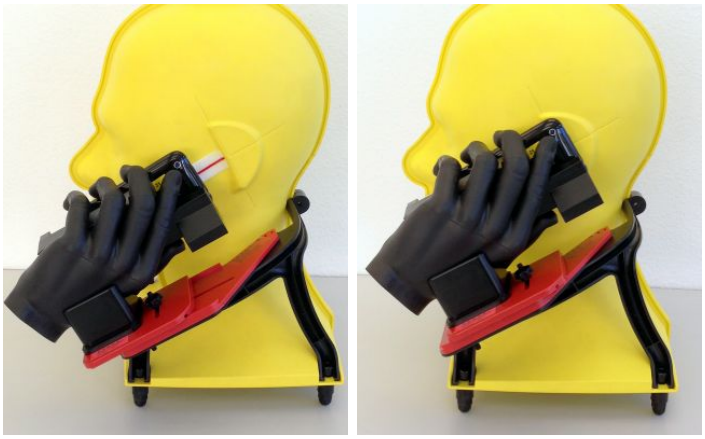
Figure 7.6: (a) Vertical and horizontal reference lines, (b) mouth and ear locations on head phantom, (c) Mask6 mounted on head phantom

(a) (b)

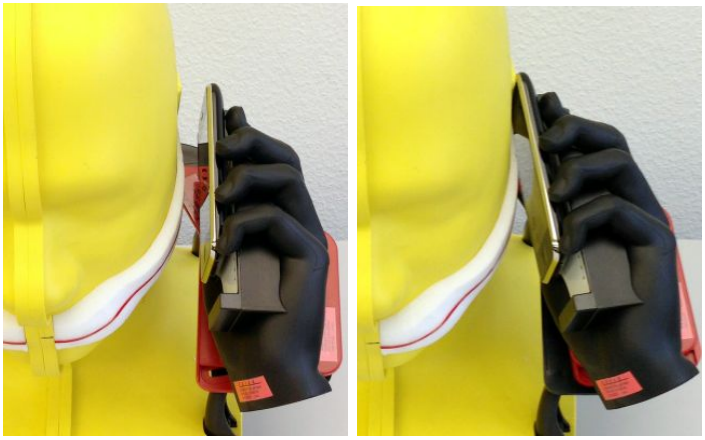
Figure 7.7: (a) Mounting the hand on the fixture/positioner using the screw at top; (b) loosening the screw at the bottom to rotate it

5. Use the horizontal movement part to translate the DUT/Hand towards the head phantom along the line passing through RE and LE until the DUT touches the ear (Figure 7.8(b)). Fix upper parts using the screw at the top of the fixture/positioner.

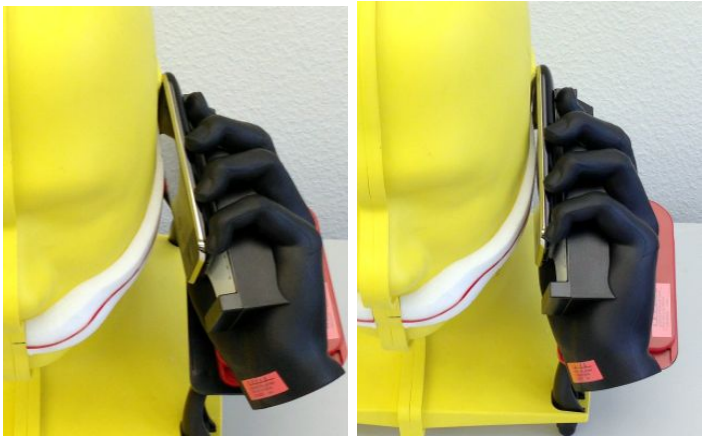
6. Loosen the screw below the fixture/positioner (Figure 7.7(b)) and rotate DUT/Hand until any point on the DUT or hand phantom is in contact with the SAM-V4.5/CTIA/BS or SAM Mask6 spacer at a point below the ear (Figure 7.8(c)).



(a)



(b)



(c)

Figure 7.8: Positioning hand phantom with DUT relative to head phantom

7.5 Data Mode

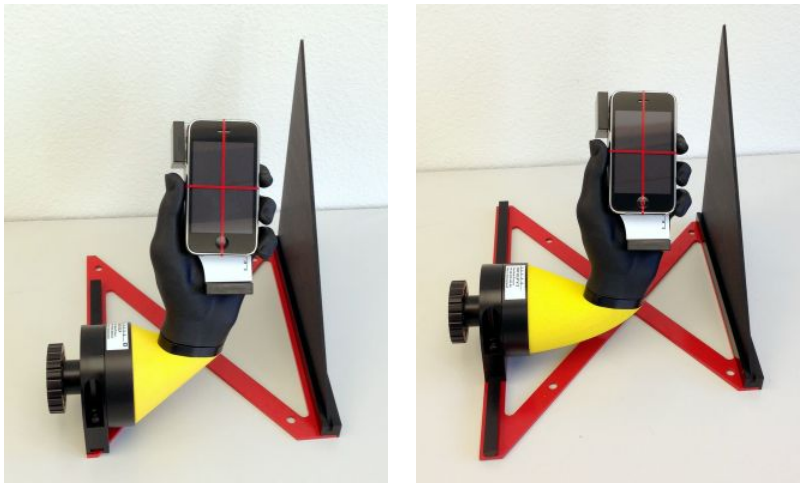
7.5.1 Hand Phantom Fixture/Positioner – Data Mode

In data mode testing, DUT shall be mounted on the SHO-V2P and oriented such that the DUT's main display is tilted 45° from vertical. For that purpose, a data mode hand phantom fixture and a wrist extension for SHO-V2P has been designed. The wrist extension material is a low loss and RF transparent foam material. The other parts of the fixture are made of a low volume, low loss solid material.

The fixture/positioner allows the user to perform rotation and movement of the hand with DUT (Device Under Test) (Figure 7.9(b)). Tilting of the mounted hand phantom is possible within a range of ±90°.

A triangular shaped alignment tool has also been designed to help the user to achieve consistent and repeatable tilting of the DUT in the hand. Note that the tool has to be removed after the DUT and the hand phantom is accurately positioned using the procedure defined below.

Note that two data mode fixture and wrist versions are available for SHO-V2RP/LP. If the PDA hand is used with Fixture V2 for Data Mode Testing SHO-RP/LP-FDMV2 and Wrist V2 for Data Mode Testing SHO-RP/LP-DWV2, the center of the DUT's main display will be closer to the rotation center. The operation procedure remains the same.



(a) (b)

Figure 7.9: Data Mode Testing (a) Fixture V1 SHO-RP/LP-FDMV1 with Wrist V1 and (b) Fixture V2 SHO-RP/LP-FDMV2 with Wrist V2, which brings the DUT's main display center (red crosshair) closer to the rotation center

7.5.2 Recommended Operation – Data Mode

The DUT positioning is performed in three steps. The recommended procedure is to first place the DUT into the grip of the hand phantom, and then to mount this assembly to the data mode fixture using the wrist extension (identical procedure for V1 and V2). Finally, the DUT in the hand phantom is positioned such that the DUT's main display is tilted 45° from vertical.

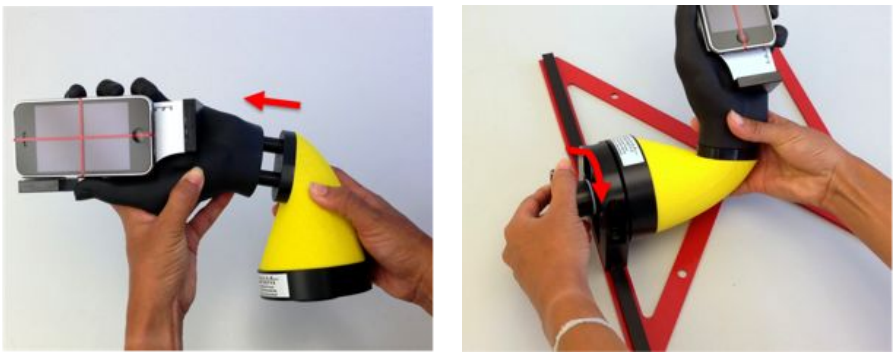
Positioning DUT relative to the hand phantom

Device positioning in SHO-V2P hand phantom for data mode is identical to that for talk mode and is already described in Section 7.4.2.

Mounting DUT and the hand phantom to the data fixture

Once the DUT is positioned on the hand phantom, the DUT and the hand phantom (DUT/Hand) will be mounted to the data fixture using the wrist extension.

1. Insert pegs of the wrist extension into the holes in the hand phantom wrist (Figure 7.10(a)).
2. Tighten the turning knob as shown in Figure 7.10(b) to mount the hand with the wrist extension to the data fixture.



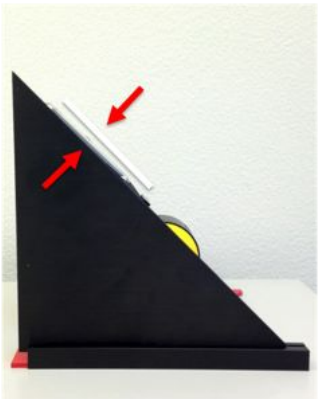
(a) (b)

Figure 7.10: (a) Inserting pegs into the wrist holes (b) mounting DUT and the hand phantom to the data fixture using the turning knob

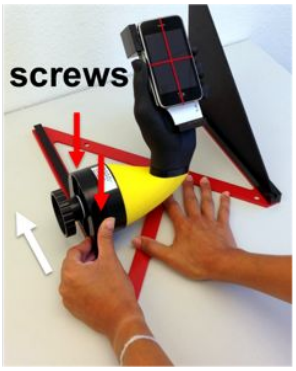
Positioning DUT relative to the hand phantom

Finally, the DUT and the hand phantom are oriented such that the DUT's main display is tilted 45° from vertical.

(a)



(b)



(c)

Figure 7.11: (a) Loosening the turning knob, (b) rotating DUT/Hand until the plane of the DUT's main display is aligned with the hypotenuse of the alignment tool. (c) After loosening the screws, the assembly can be moved in a horizontal direction until the center of the display (red crosshair) is on top of the center of rotation.

1. Loosen the turning knob (Figure 7.11(a)) and rotate the DUT/Hand until the plane of DUT's main display is aligned with the hypotenuse (the longest side of the right triangle) of the alignment tool (Figure 7.11(a)). Tighten the turning knob to fix DUT/Hand position.

2. If necessary, loosen the screws shown in Figure 7.11(a) to move DUT/Hand and the slider assembly along the rail in a horizontal direction. Fix the assembly by tightening the screws.

Chapter 8

SAM Hand OTA Phantom SHO-V2RW/LW (for PDA (Ultra Wide) Phones)

8.1 Introduction

The SHO-V2RW and SHO-V2LW (right and left hand phantoms) are homogeneous anthropomorphically shaped hand phantoms suitable for use with ultra wide PDA (Personal Digital Assistant – Wide) mobile phones for head and hand (talk mode) testing or hand only (data mode) testing. They provide accurate radiation pattern or total radiated power testing of ultra wide PDA mobile phones. Thoroughly designed fixture/positioners and spacers are available to enable precise and repeatable positioning of the device in the hand. The dimensions and material of the hand phantoms, material of the spacers and other accessories are compliant with the CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.x.

8.2 Construction

The SHO-V2 hand phantoms are manufactured from a silicon- and carbon-based mixture (color: black). The hand target parameters based on real hand measurements and parameters are compliant with CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision V3.x. The hand is sufficiently flexible to grip the range of device sizes and sufficiently stiff to remain in consistent grip. The spacer is manufactured from a low loss and RF transparent hollow material with a wall thickness less than 2 mm. The white cover on the spacer is made of a low volume, low loss solid material.

(a) (b)

Figure 8.1: (a) SHO-V2RW and (b) SHO-V2LW

8.3 Dimensions of Hand Phantom and Spacer

Geometry

Grip is according to human factor study and the dimensions of the hand are compliant with CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision V3.x.

Hand

Height	180 mm
Wrist width	61 mm
Hand width	120 mm

Spacer

Height	135 mm
Width	70 mm

8.4 Talk Mode

8.4.1 Hand Phantom Fixture/Positioner – Talk Mode

SHO-V2 is available with an integrated lightweight high precision fixture/positioner which is fully compatible with the SAM-V4.5/CTIA/BS. It enables precise positioning of a left or right hand phantom with the device in a tilted position on either sides of the head phantom with high repeatability.

The fixture/positioner consists of three parts which allow the user to perform rotation and movement of the hand with DUT (Device Under Test) (Figure 8.3). Tilting of the mounted hand phantom is possible within a range of ±11°(controllable by marks with 1° resolution).

(a) (b)

Figure 8.2: (a) SHO-V2RW Hand phantom and (b) its spacer

8.4.2 Recommended Operation – Talk Mode

The DUT positioning is performed in two steps. The recommended procedure is to first place the DUT into the grip of the hand phantom, and then to position this assembly against the SAM-V4.5/CTIA/BS head phantom.

Adjusting hand phantom height

The position of the hand phantom on the horizontal movement part of the fixture should be adjusted in order to align the vertical line of the DUT to the line passing through points RE and M on the head phantom (Figure 8.5).

1. Measure width (w) of the DUT in mm. The required height adjustment is calculated with: h = (92 − w) /2
2. Choose a combination of spacer plates provided with the hand phantom (Figure 8.4(a): 1 mm, 2x2 mm, 4 mm) to achieve the required h value calculated in Step 1. For example, a DUT with a width of 84 mm will require the use of one 4 mm spacer plates to accommodate the h value.
3. Loosen the screws connecting the fixture part to the hand cushion (Figure 8.4(b)). Insert spacer plates between the fixture and the hand cushion as shown in Figure 8.4(c).
4. Re-secure the fixture and hand cushion using the screws.

Positioning DUT relative to the hand phantom

Device positioning with respect to the SHO-V2RW hand phantom is equal to the PDA hand, which is described in Chapter 7.4.2 on page 58.

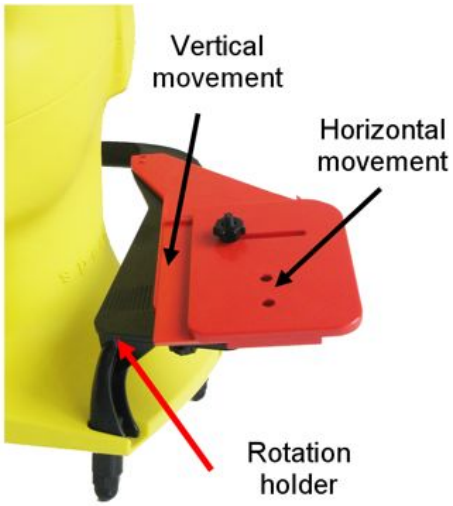


Figure 8.3: Hand phantom fixture/positioner – Talk Mode

Positioning DUT and hand phantom relative to the head phantom

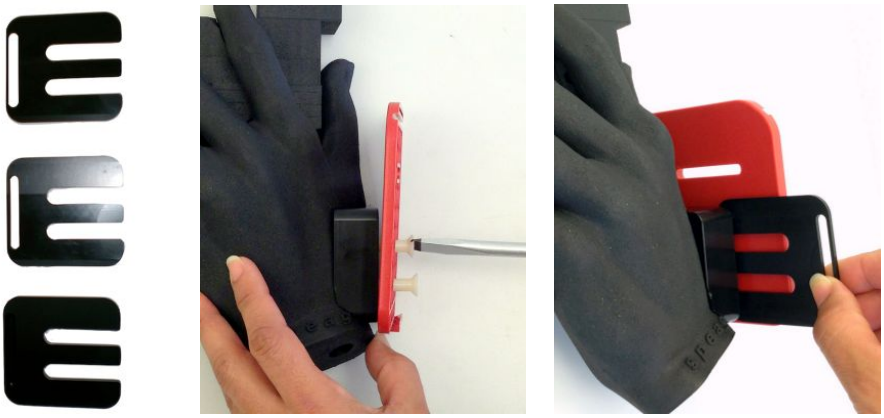
Once the DUT is positioned on the hand phantom, the DUT and the hand phantom (DUT/Hand) will be placed in a tilted position (cheek + 6°) on the head phantom.

1. Define two imaginary lines on the front side of the DUT as shown in Figure 8.5(a). The vertical line passes through the midpoint of the width of the DUT at the level of acoustic output (point A) to the midpoint of the width at the bottom of the DUT (point B). The horizontal line is perpendicular to the vertical line and intersects with the vertical line at point A.

2. The locations of the left ear (LE), right ear (RE) and mouth (M) points on the SAM-V4.5/CTIA/BS head phantom are shown in Figure 8.5(b). Mount Mask6 on the head phantom (Figure 8.5(c)). We recommend using two small pieces of double-sided tape at the center and at the mouth locations of the mask to mount it to the head phantom.

3. Place DUT/Hand on the fixture/positioner and fix them using the screw (Figure 8.6(a)).

4. Using the vertical movement part of the fixture/positioner, move the DUT close to the surface of the SAM head phantom such that point A is on the (virtual) extension of the line passing through points RE and LE on the head phantom (Figure 8.7(a)).

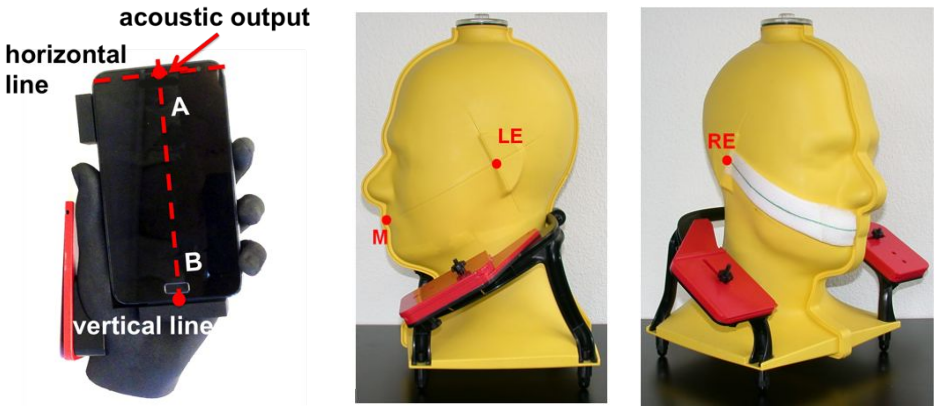


(a) (b) (c)

Figure 8.4: Adjusting hand phantom height: (a) set of spacer plates, (b),(c) inserting spacer plates

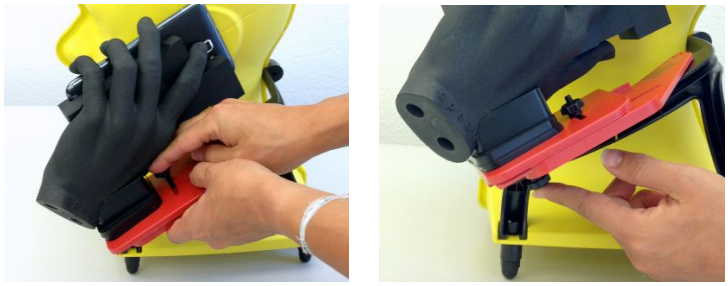
5. Use the horizontal movement part to translate the DUT/Hand towards the head phantom along the line passing through RE and LE until the DUT touches the ear (Figure 8.7(b)). Fix upper parts using the screw at the top of the fixture/positioner.

6. Loosen the screw below the fixture/positioner (Figure 8.6(b)) and rotate DUT/Hand until any point on the DUT or hand phantom is in contact with the SAM-V4.5/CTIA/BS or SAM Mask6 spacer at a point below the ear (Figure 8.7(c)).



(a) (b) (c)

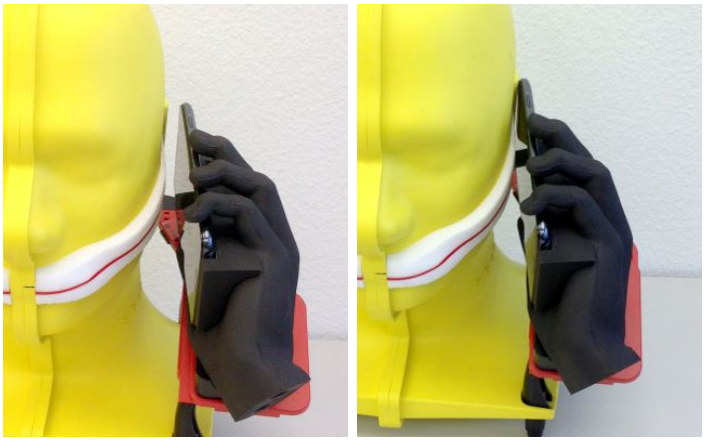
Figure 8.5: (a) Vertical and horizontal reference lines, (b) mouth and ear locations on head phantom, (c) Mask6 mounted on head phantom



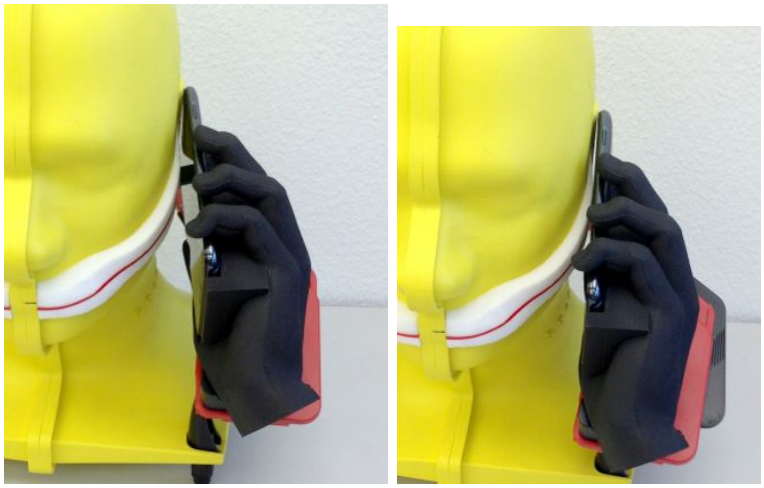
(a) (b)

Figure 8.6: (a) Mounting the hand on the fixture/positioner using the screw at top; (b) loosening the screw at the bottom to rotate it

(a)



(b)



(c)

Figure 8.7: Positioning hand phantom with DUT relative to head phantom

8.5 Data Mode

8.5.1 Hand Phantom Fixture/Positioner – Data Mode

In data mode testing, DUT shall be mounted on the SHO-V2RW/LW and oriented such that the DUT's main display is tilted 45° from vertical. For that purpose, a data mode hand phantom fixture and a wrist extension for SHO-V2RW/LW has been designed. The wrist extension material is a low loss and RF transparent foam material. The other parts of the fixture are made of a low volume, low loss solid material.

The fixture/positioner allows the user to perform rotation and movement of the hand with DUT (Device Under Test) (Figure 8.8). Tilting of the mounted hand phantom is possible within a range of ±90°.

A triangular shaped alignment tool has also been designed to help the user to achieve consistent and repeatable tilting of the DUT in the hand. Note that the tool has to be removed after the DUT and the hand phantom is accurately positioned using the procedure defined below.

Note that only Fixture V2 for Data Mode Testing SHO-RW/LW-FDMV2 should be used with SHO-V2RW/LW, which is optimised to bring the center of the DUT closer to the rotation center.

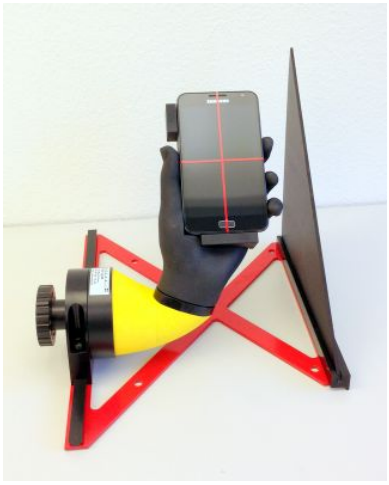


Figure 8.8: Fixture V2 for Data Mode Testing SHO-RW/LW-FDMV2 with Wrist V2 SHO-RW/LW-DWV2, which brings the DUT's main display center (red crosshair) close to the rotation center

8.5.2 Recommended Operation – Data Mode

The DUT positioning is performed in three steps. The recommended procedure is to first place the DUT into the grip of the hand phantom, and then

to mount this assembly to the data mode fixture using the wrist extension. Finally, the DUT in the hand phantom is positioned such that the DUT's main display is tilted 45° from vertical.

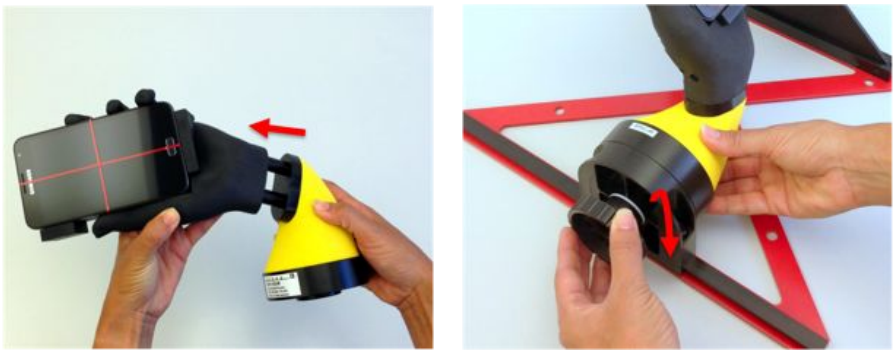
Positioning DUT relative to the hand phantom

Device positioning in SHO-V2RW/LW hand phantom for data mode is identical to that for talk mode and is already described in Section 8.4.2 (or Section 7.5.2 respectively).

Mounting DUT and the hand phantom to the data fixture

Once the DUT is positioned on the hand phantom, the DUT and the hand phantom (DUT/Hand) will be mounted to the data fixture using the wrist extension.

1. Insert pegs of the wrist extension into the holes in the hand phantom wrist (Figure 8.9(a)).
2. Tighten the turning knob as shown in Figure 8.9(b) to mount the hand with the wrist extension to the data fixture.



(a) (b)

Figure 8.9: (a) Inserting pegs into the wrist holes (b) mounting DUT and the hand phantom to the data fixture using the turning knob

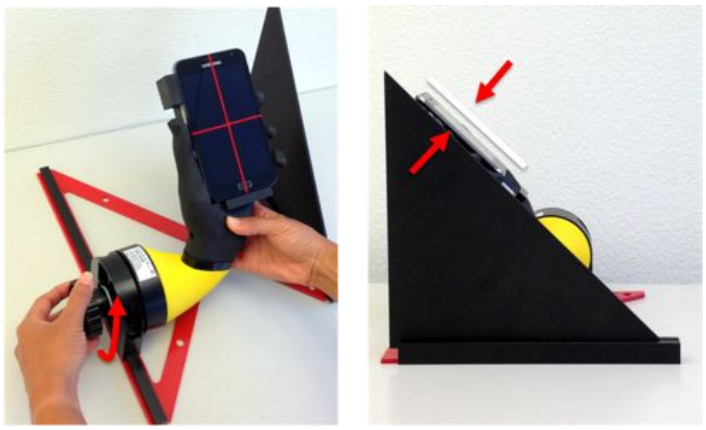
Positioning DUT relative to the hand phantom

Finally, the DUT and the hand phantom are oriented such that the DUT's main display is tilted 45° from vertical.

1. Loosen the turning knob (Figure 8.10(a)) and rotate the DUT/Hand until the plane of DUT's main display is aligned with the hypotenuse

(the longest side of the right triangle) of the alignment tool (Figure 8.10(a)). Tighten the turning knob to fix DUT/Hand position.

2. If necessary, loosen the screws shown in Figure 8.10(a) to move DUT/Hand and the slider assembly along the rail in a horizontal direction. Fix the assembly by tightening the screws.



(a) (b)

(c)

Figure 8.10: a) Loosening the turning knob, (b) rotating DUT/Hand until the plane of the DUT's main display is aligned with the hypotenuse of the alignment tool. (c) After loosening the screws, the assembly can be moved in a horizontal direction until the center of the display (red crosshair) is on top of the center of rotation.

Chapter 9

SAM Hand OTA Phantom SHO-V2RD/LD (Data Mode-Narrow Phones)

9.1 Introduction

The SHO-V2RD and SHO-V2LD (right and left hand phantoms) are homogeneous anthropomorphically shaped hand phantoms suitable for use with narrow mobile phones (widths between 40 mm and 56 mm) for hand only (data mode) testing. They provide accurate radiation pattern or total radiated power testing of narrow mobile phones in data mode. Thoroughly designed fixture/positioners and spacers are available to enable precise and repeatable positioning of the device in the hand. The hand phantoms, spacers and other accessories are compliant with the CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.x.

9.2 Construction

The SHO-V2 hand phantoms are manufactured from a silicon- and carbon-based mixture (color: black). The hand target parameters based on real hand measurements and parameters are compliant with CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.x. The hand is sufficiently flexible to grip the range of device sizes and sufficiently stiff to remain in consistent grip. The spacer is manufactured from a low loss and RF transparent hollow material with a wall thickness less than 2 mm. The measurement scale on the spacer is made of a low volume, low loss solid material.

(a) (b)

Figure 9.1: (a) SHO-V2RD and (b) SHO-V2LD

9.3 Dimensions of Hand Phantom and Spacer

Geometry

Grip and dimensions are according to human factor studies and hand anthropometric research. They are compliant with CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.x.

Hand

Height	168 mm
Wrist width	61 mm
Hand width	97 mm

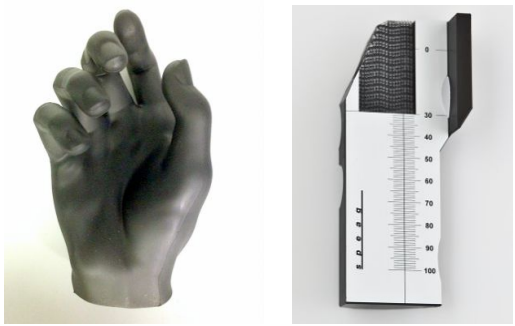
Spacer

Height	128 mm
Width	54 mm

9.4 Hand Phantom Fixture/Positioner – Data Mode

In data mode testing, DUT shall be mounted on the SHO-V2RD/LD and oriented such that the DUT's main display is tilted 45° from vertical. For that purpose, a data mode hand phantom fixture and wrist extensions for SHO-V2RD/LD has been designed. The wrist extension material is a low loss and RF transparent foam material. The other parts of the fixture are made of a low volume, low loss solid material.

The fixture/positioner allows the user to perform rotation and movement of the hand with DUT (Device Under Test) (Figure 9.3). Tilting of the mounted hand phantom is possible within a range of ±90°.

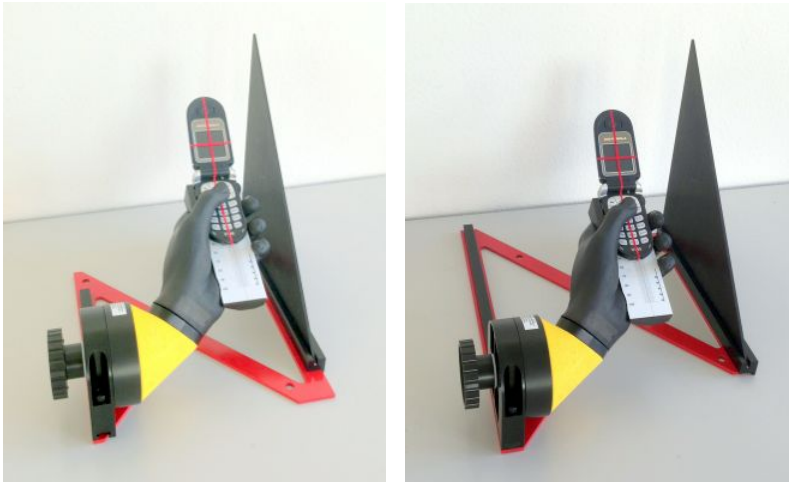


(a) (b)

Figure 9.2: (a) SHO-V2RD Hand phantom and (b) its spacer

A triangular shaped alignment tool has also been designed to help the user to achieve consistent and repeatable tilting of the DUT in the hand. Note that the tool has to be removed after the DUT and the hand phantom is accurately positioned using the procedure defined below.

Note that SHO-V2RD/LD can be used together with Fixture V1 and V2 for Data Mode Testing SHO-RP/LP-FDMV1/2. In combination with V2 the center of the DUT will be closer to the rotation center.



(a) (b)

Figure 9.3: Data Mode Testing (a) Fixture V1 SHO-RD/LD-FDMV1 with Wrist V1 and (b) Fixture V2 SHO-RD/LD-FDMV2 with Wrist V2, which brings the DUT's main display center (red crosshair) closer to the rotation center

9.5 Alignment Tool B

The alignment tool is used to measure the reference position of the bottom of the DUT with arbitrary chin curvature so that the user can align the ring fingertip with the bottom of the DUT consistently.

The tool consists of a flat slab with a raised guiding strip along one side. The guiding strip has a 60° angled corner at the bottom which enables to obtain the desired amount of contact according to human factor studies. The scale on the tool agrees with the scale on the hand phantom spacer.

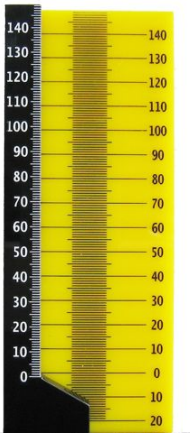


Figure 9.4: Alignment tool B

9.6 Recommended Operation – Data Mode

The DUT positioning is performed in three steps. The recommended procedure is to first place the DUT into the grip of the hand phantom, and then to mount this assembly to the data mode fixture (identical procedure for V1 and V2) using the wrist extension. Finally, the DUT in the hand phantom is positioned such that the DUT's main display is tilted 45° from vertical.

Positioning DUT relative to the hand phantom

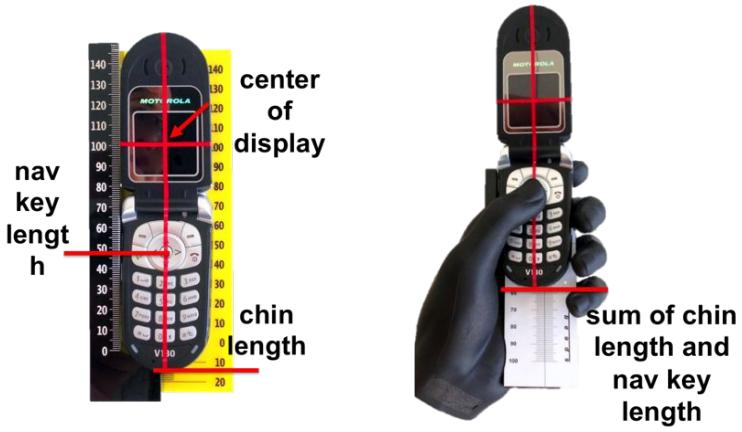
Device positioning with respect to the hand phantom is performed using the hand phantom spacer and the alignment tool B.

1. Place the DUT on the alignment tool B and fit it into the corner between the slab and the guiding strip. Slide the DUT down until it reaches the angled corner.
2. Record the chin length from the scale at the bottom of the alignment tool B ('chin length' in Figure 9.5(a)).

3. Record the location of the navigation key (or the '2' key, if no navigation key is present) on the side ruler of the alignment tool B ('nav key length' Figure 9.5(a)). Use the key's center as the reference.

4. Add two readings from Step 2 and 3 together. If the sum is less than 30 mm, then use 30 mm instead.

5. Place the DUT on the spacer and between the fingers of the hand phantom. Align the side of the DUT with the side wall of the spacer. The bottom edge of the DUT should be placed on the spacer at the ruling corresponding to the value obtained in Step 4 (Figure 9.5(a)). We recommend using short (~1.5 cm) "3M Dual-Lock" strip provided with the hand phantom to fix the DUT to the hand phantom.



(a) (b)

Figure 9.5: Positioning DUT relative to the hand phantom

Mounting DUT and the hand phantom to the data fixture

Once the DUT is positioned on the hand phantom, the DUT and the hand phantom (DUT/Hand) will be mounted to the data fixture using the wrist extension.

1. Insert pegs of the wrist extension into the holes in the hand phantom wrist (Figure 9.6(a)).

2. Tighten the turning knob as shown in Figure 9.6(b) to mount the hand with the wrist extension to the data fixture.

(a) (b)

Figure 9.6: (a) Inserting pegs into the wrist holes (b) mounting DUT and the hand phantom to the data fixture using the turning knob

Positioning DUT relative to the hand phantom

Finally, the DUT and hand phantom are oriented such that the DUT's main display is tilted 45° from vertical.

1. Loosen the turning knob (Figure 9.7(a)) and rotate the DUT/Hand until the plane of the DUTs main display is aligned with the hypotenuse (the longest side of the right triangle) of the alignment tool (Figure 9.7(b)). Tighten the turning knob to fix DUT/Hand position.
2. If necessary, loosen the screws shown in Figure 9.7(c) to move the DUT/Hand and the slider assembly along the rail in a horizontal direction. Fix the assembly by tightening the screws.

(a) (b)

(c)

Figure 9.7: (a) Loosening the turning knob, (b) rotating DUT/Hand until the plane of the DUT's main display is aligned with the hypotenuse of the alignment tool. (c) After loosening the screws, the assembly can be moved in a horizontal direction until the center of the display is on top of the center of rotation.

Chapter 10

SAM Hand OTA Phantom SHO-RTABV2/LTABV2 (for Tablets)

10.1 Introduction

The SHO-RTABV2 and SHO-LTABV2 (SHO Right and Left TABlet hands V2) are homogeneous anthropomorphically shaped hand phantoms suitable for use with tablets for hand only (data mode) testing. They enable accurate measurement of radiation patterns and total radiated power of tablet devices. The thoroughly designed fixture and spacers are available to facilitate precise and repeatable positioning of the device in the hand. The dimensions and material of the hand phantoms and the material of the spacers and other accessories are compliant with the CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.x.

(a) (b)

Figure 10.1: (a) SHO-LTABV2 and (b) SHO-RTABV2

10.2 Construction

The SHO V2 hand phantoms are manufactured from a silicone- and carbon-based mixture (color: black). The hand target parameters based on real hand measurements are compliant with the CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.x. The hand is sufficiently flexible to grip a range of device thicknesses and sufficiently stiff to maintain a consistent grip. The spacer is manufactured from a low-loss and RF transparent hollow material with a wall thickness less than 2 mm. The white cover on the spacer is made of a low volume, low-loss solid material.

10.3 Dimensions of Hand Phantom and Spacer

Geometry

The grip is according to a human factor study, and the dimensions of the hand phantoms are compliant with the CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.x.

Hand

Height	175 mm
Wrist width	61 mm
Hand width	90 mm

Spacer

Height	150 mm
Width	63 mm

(a) (b)

Figure 10.2: (a) SHO-LTABV2 Hand phantom and (b) its spacer

10.4 Hand Phantom Fixture/Positioner – Testing Mode

In testing mode, the DUT is mounted between the right and the left hand phantoms (SHO-RTABV2 and SHO-LTABV2) and oriented such that the DUT's main display is tilted 45° from vertical. For that purpose, a fixture and wrist extensions for both right and left hand phantoms have been designed with a fixed mounting angle. The wrist extensions are made of a hollow low-loss and RF transparent material. The other parts of the fixture are made of a low volume, low-loss solid material.

The fixture allows the user to perform axial translation movements of the hands for a tight grip of various device widths. (Figure 10.4)

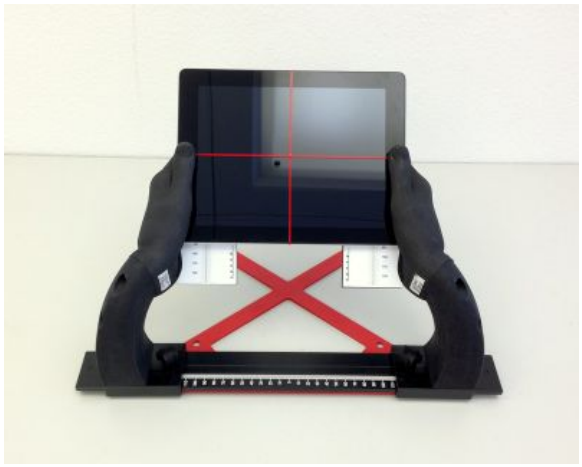


Figure 10.3: SHO-FX-HOTV2 - SHO Fixture X for Hand-Only-Testing V2 with right and left wrists (SHO-RTAB/LTAB-DWV1), hands, and DUT

10.5 Recommended Operation – Testing Mode

The DUT positioning is performed in three steps. The recommended procedure is to first mount both hand phantoms, right and left, to the corresponding wrist extensions, then mount this assembly to the fixture. Finally, the DUT is positioned between the two hand phantoms and aligned on the spacer.

Mounting the hand phantom to the fixture

For all following steps, be sure to not mix up right and left parts.

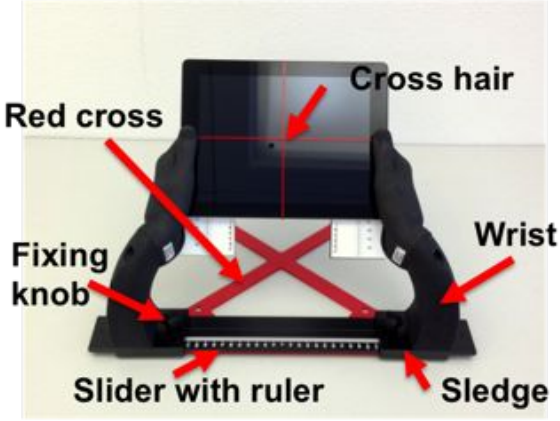


Figure 10.4: Fixture SHO-FX-HOTV2 parts.

1. Insert the pegs of the wrist extension into the holes in the hand phantom wrist (Figure 10.5(a)). Fix the hand phantom to the wrist extension with the two screws provided (Figure 10.5(b) and 10.5(c)).

2. Mount the assembly on the fixture by sliding the sledge in towards the center from the side (right hand assembly from the right side, left hand assembly from the left side). When sliding the assembly, the fixing knob should be loosened (Figure 10.6).

Positioning the DUT to the hand phantom and the fixture

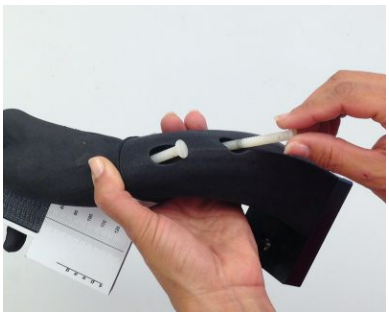
Once the hands are mounted to the sledge and the sledge is placed on the fixture slider, the DUT can be easily positioned between the right and left hand phantoms. We recommend that the center of the display be aligned with the rotation center.

1. Place the cross hair over the DUT's display to indicate rotation center. We recommend that the display center be lined with the rotation center (see Figure 10.4).

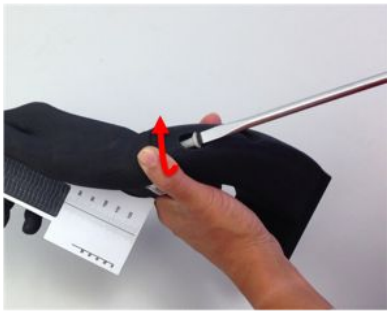
2. Align the display center line with the zero-point marker on the spacer (Figure 10.7(a)). Place the DUT under the thumb to the hand (Figure 10.7(b)). We recommend using the short (∼1.5 cm) "3M Dual-Lock" strip provided with the hand phantom to fix the DUT to the hand phantom spacer.

3. Shift the sledge together with the wrist, the hand, and the DUT such that the center of the display overlaps the center of the red cross of the fixture (rotation center), as indicated in Figure 10.8(a). Tighten

(a)



(b)



(c)

Figure 10.5: (a) Inserting the pegs into the hand's wrist, (b) placing the screws, and (c) tightening them.

the fixing knob (Figure 10.8(b)). If necessary, support the other side of the DUT to prevent it from falling.

4. Read the position on the ruler and shift the left hand to the same mark on the left hand side (Figure 10.9). Tighten the fixing knob.

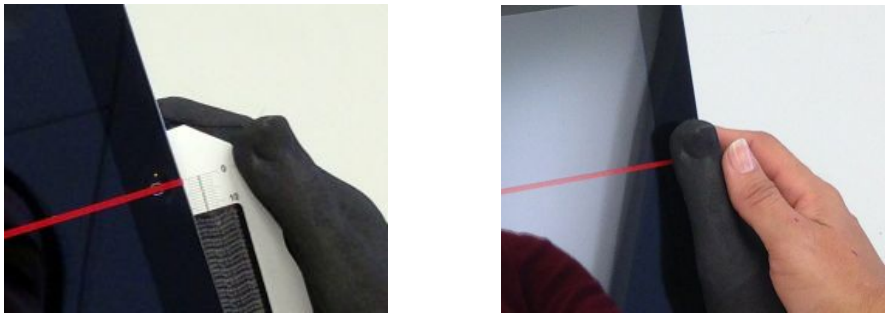
5. Place the DUT under the left thumb and on the left spacer. Align the red mark on the DUT with the zero-point on the spacer ruler as before for the right hand.

Mounting the wrist to the sledge

Unscrew the three screws according Figure 10.10. Replace the corresponding wrist and tighten the screws again.

(a) (b)

Figure 10.6: (a) Mounting the right hand to the fixture and (b) fixing the knob.

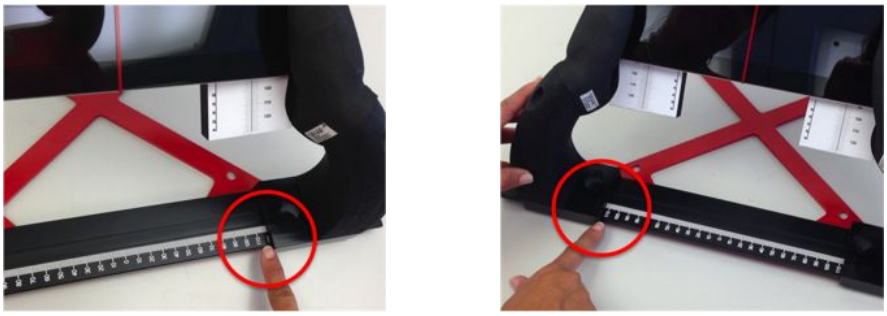


(a) (b)

Figure 10.7: (a) Aligning the display center line with the zero-point marker and (b) pushing the DUT under the thumb.

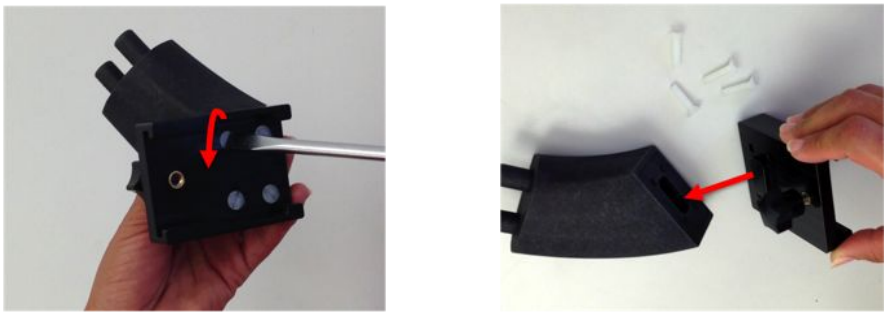
(a) (b)

Figure 10.8: (a) Aligning the display center line with the rotation center and (b) tightening the knob.



(a) (b)

Figure 10.9: Aligning the DUT with the rotation center.



(a) (b)

Figure 10.10: (a) Removing the screws from the sledge and (b) mounting the wrist.

Chapter 11

SAM Hand OTA Phantom SHO-RTHGV2/LTHGV2 (for Two-Hand-Grip)

11.1 Introduction

The SHO-RTHGV2 and SHO-LTHGV2 (SHO Right and Left Two Hand Grip hands V2) are homogeneous anthropomorphically shaped hand phantoms suitable for use with brick phones for hand only (data mode) testing. They enable accurate measurement of radiation patterns and total radiated power of brick shaped devices used in, e.g., gaming mode. The thoroughly designed fixture and spacers are available to facilitate precise and repeatable positioning of the device in the hand. The dimensions and material of the hand phantoms, material of the spacers and other accessories are compliant with the CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.x.

(a) (b)

Figure 11.1: (a) SHO-LTHGV2 and (b) SHO-RTHGV2

11.2 Construction

The SHO V2 hand phantoms are manufactured from a silicone- and carbon-based mixture (color: black). The hand target parameters based on real hand measurements are compliant with the CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.x. The hand is sufficiently flexible to grip a range of devices and sufficiently stiff to maintain a consistent grip. The spacer is manufactured from a low-loss and RF transparent hollow material with a wall thickness less than 2 mm. The white cover on the spacer is made of a low volume, low-loss solid material.

11.3 Dimensions of Hand Phantom and Spacer

Geometry

The dimensions of the hand phantoms are compliant with the CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.x.

Hand

Height	155 mm
Wrist width	61 mm
Hand width	100 mm

Spacer

Height	74 mm
Width	56 mm

(a) (b)

Figure 11.2: (a) SHO-RTHGV2 Hand phantom and (b) its spacer

11.4 Hand Phantom Fixture/Positioner – Testing Mode

In testing mode, the DUT is mounted between the right and the left hand phantoms (SHO-RTHGV2 and SHO-LTHGV2) and oriented such that the DUT's main display is tilted 45° from vertical. For that purpose, a fixture, and wrist extensions for both right and left hand phantoms have been designed with a fixed mounting angle. The wrist extensions are made of a hollow low-loss and RF transparent material. The other parts of the fixture are made of a low volume, low-loss solid material.

The fixture allows the user to perform axial translation movements of the hands for a tight grip of various device widths. (Figure 11.4)

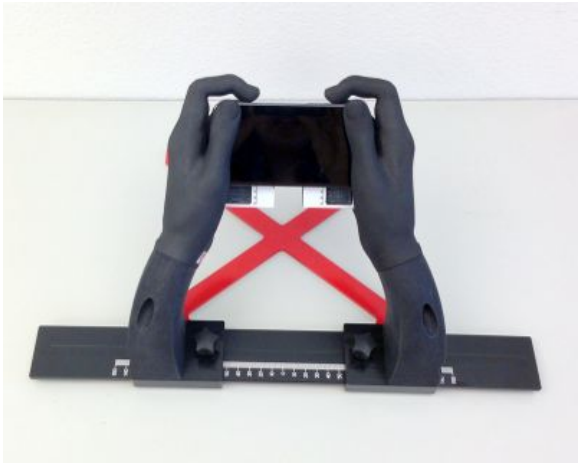


Figure 11.3: SHO-FX-HOTV2 - SHO Fixture X for Hand-Only-Testing V2 with right and left wrists (SHO-RTHG/LTHG-DWV1), hands, and DUT

11.5 Recommended Operation – Testing Mode

The DUT positioning is performed in three steps. The recommended procedure is to first mount both hand phantoms, right and left, to the corresponding wrist extensions, then mount this assembly to the fixture. Finally, the DUT is positioned between the two hand phantoms and aligned on the spacer.

Mounting the hand phantom to the fixture

For all following steps, be sure to not mix up right and left parts.

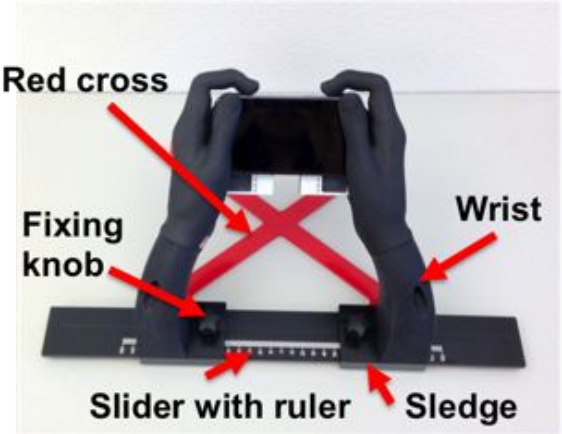


Figure 11.4: Fixture SHO-FX-HOTV2 parts.

1. Insert the pegs of the wrist extension into the holes in the hand phantom wrist (Figure 11.5(a)). Fix the hand phantom to the wrist extension with the two screws provided (Figure 11.5(b) and 11.5(c)).

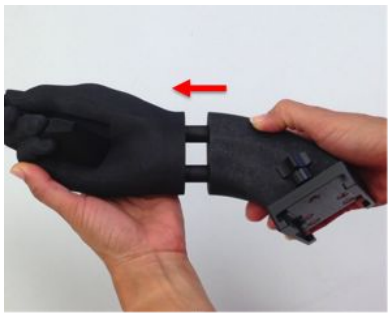
2. Mount the assembly to the fixture by sliding the sledge in from the side (right hand assembly from the right side, left hand assembly from the left side). When sliding in, the fixing knob should be loosened (Figure 11.6).

Positioning the DUT relative to the hand phantom and the fixture

Once the hands are mounted to the sledge and the sledge is placed on the fixture slider, the DUT can be easily positioned between the right and left hand phantoms. We recommend that the center of the display be aligned with the rotation center.

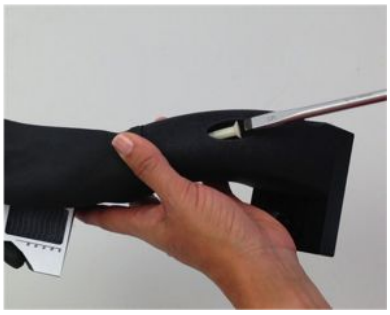
1. Place the cross hair over the DUT's display to indicate the rotation center. In the vertical, we recommend drawing the cross hair line through the center and in the horizontal at 30 mm below the upper edge (Figure 11.7).

2. Place the DUT first under the right hand's thumb and on the spacer (Figure 11.8(a)). Align the cross hair mark on the DUT with the indicator on the spacer (the indicator is only a recommended position). Note that the index finger tip should press against the upper edge of the device (Figure 11.8(b)). Then place the DUT on the hand. We recommend using the short (∼1.5 cm) "3M Dual-Lock" strip provided with the hand phantom or double sided tape to fix the DUT to the hand phantom spacer.



(a)

(b)



(c)

Figure 11.5: (a) Inserting pegs into the hand's wrist (b) placing the screws, and (c) tightening them.

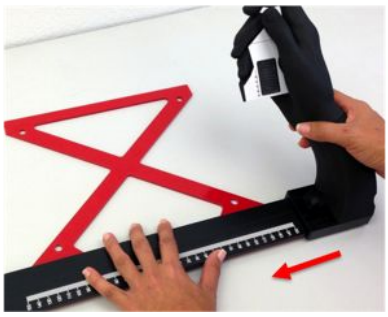
3. Shift the sledge together with the wrist, the hand, and the DUT such that the cross hair overlaps the center of the red cross of the fixture (rotation center), as indicated in Figure 11.9(a). Tighten the fixing knob (Figure 11.9(b)). If necessary, support the other side of the DUT to prevent it from falling.

4. Read the position on the ruler and shift the left hand to the same mark on the left hand side (Figure 11.10). Tighten the fixing knob.

5. Place the DUT under the left thumb and on the left spacer. Align the cross hair line on the DUT with the indicator on the spacer as before for the right hand.

Mounting the wrist to the sledge

Unscrew the three screws according Figure 10.10. Replace the corresponding wrist and tighten the screws again.



(a)

(b)

Figure 11.6: (a) Mounting the right hand to the fixture and (b) fixing the knob.

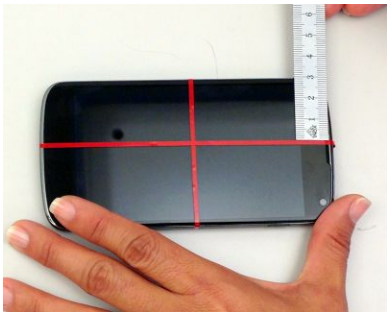
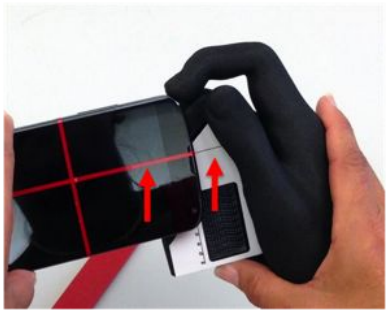
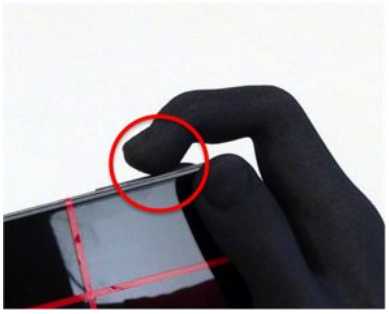


Figure 11.7: Marking the DUT: vertical line through display center, horizontal line 30 mm below the upper edge.



(a)



(b)

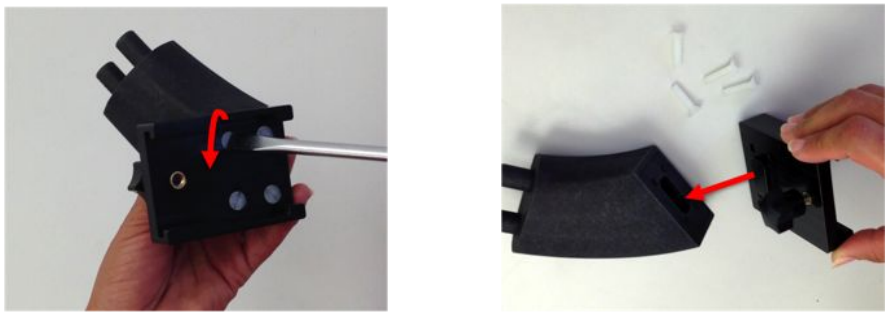
Figure 11.8: (a) Aligning the display center line with the spacer marker (b) index finger presses on the upper edge of the device.

(a) (b)

Figure 11.9: (a) Aligning the cross hair with the rotation center and (b) tightening the knob.

(a) (b)

Figure 11.10: Aligning the DUT with the rotation center.



(a) (b)

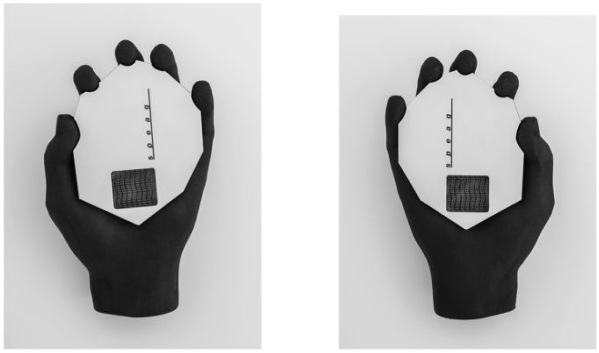
Figure 11.11: (a) Removing the screws from the sledge and (b) mounting the wrist.

Chapter 12

SAM Hand OTA Phantom SHO-V2RLAP/LLAP

12.1 Introduction

The Hand (SHO) Phantom Version 2 Right for Laptops (SHO-V2RLAP) and the Hand Phantom Version 2 Left for Laptops SHO-V2LLAP are a pair of hands designed to test the effect of the user?s hands on the over-the-air wireless performance of laptops, notebooks, and wireless keyboards. The hand size and material correspond to those defined by CTIA and 3GPP and represent average hand size.



(a) (b)

Figure 12.1: (a) SHO-V2LLAP and (b) SHO-V2RLAP

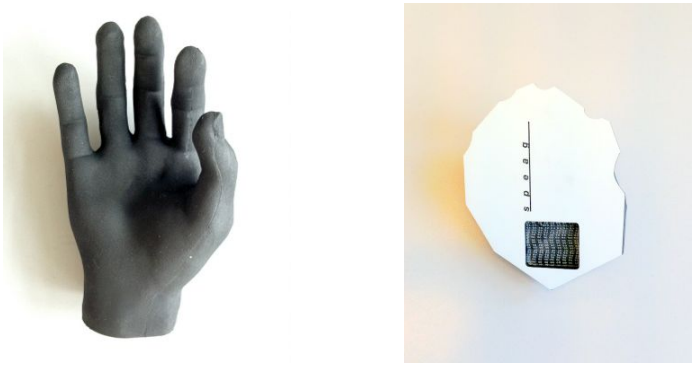
The hand posture represents the average resting position of the hand on the English keyboard, i.e., the thumbs on/close to the space-bar, the right index finger on/close to the J-key and the left index finger on/close to the F-key. To allow accurate and repeatable positioning of the hands on the device, supporting low-loss spacers have been integrated into the hands. The hands are mounted on the DUT with Velcro tape (glued to the spacers).

A laptop fixture that allows to adapt various sizes of laptops, notebooks, and keyboards to be adapted to a turn table with its rotation axis aligned to the center of the DUT is currently under development. SPEAGs laptop fixture is recommended but not required for the test.

12.2 Construction

The SHO-V2 hand phantoms are manufactured from a silicone- and carbon-based mixture (color: black). The hand target parameters, based on real hand measurements, are compliant with CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision V3.x. The hand has a certain elasticity such that the fingers adapt to key-height variations. The spacer is manufactured from low-loss hollow plastic with a wall thickness of less than 2 mm.

12.3 Dimensions of Hand Phantom and Spacer



(a) (b)

Figure 12.2: (a) SHO-V2RLAP hand phantom and (b) spacer.

Geometry

Dimensions of the hand phantoms are compliant with CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision V3.x.

Hand

Height	190 mm
Wrist width	61 mm
Hand width	115 mm

Spacer

Height	105 mm
Width	90 mm

12.4 Hand Phantom – Operating Mode

In operating mode, both hand phantoms are mounted on the keyboard of the DUT. The recommended procedure is to first define the orientation of the hands on the keyboard and then attach the hands to the DUT. Spacers and Velcro tape enable repeatable and easy positioning.

Figure 12.3: SHO-V2LLAP and SHO-V2RLAP hand phantoms positioned on a laptop device.

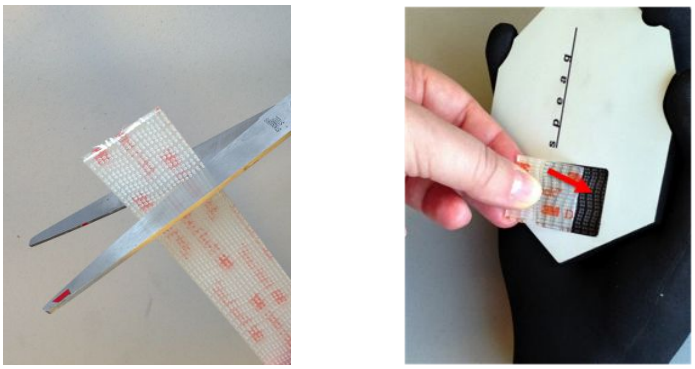
Mounting the hand phantom to the DUT

1. We recommend that the hands be placed symmetrically on the keyboard in the basic position for typing, with the thumbs positioned on the space-bar, the right index finger close to the J-bar and the left index finger close to the F-key (see Figure 12.4). Mark or memorise the hand position on the DUT.

2. We recommend the use of the short (∼1.5 cm) "3M Dual-Lock" Velcro tape provided with the hand phantom to fix the hand phantoms to the DUT. Cut the tape such that it fits in the corresponding cutout of the spacer (Figure 12.5(a)). Attach the Velcro to the spacer (Figure 12.5(b)).

3. Remove the protective foil from the Velcro tape (Figure 12.8(a)) and mount the hand at the required position (Figure 12.8(b)) .

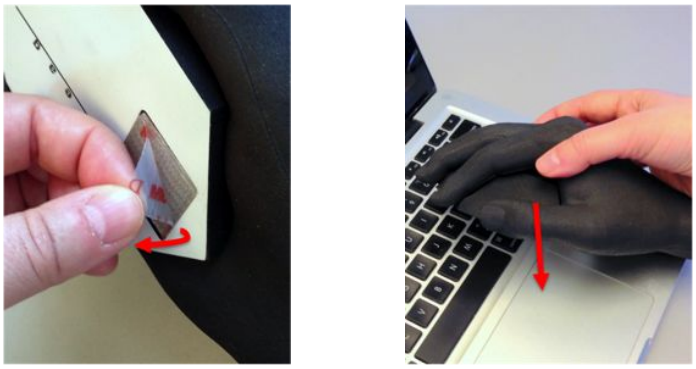
Figure 12.4: Defining position of the fingers on the DUT.



(a) (b)

Figure 12.5: (a) Cutting the Velcro tape and (b) attaching to the spacer.

4. Should the hands become loose during vertical rotation, we recommend the use of an additional piece of flexible tape to fix the hands to the DUT (Figure 12.9).



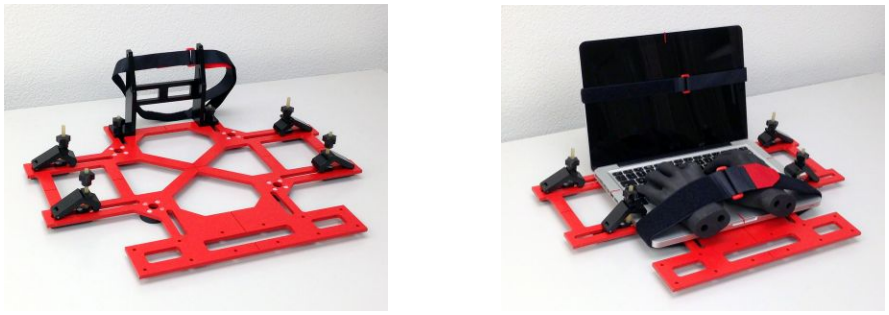
(a) (b)

Figure 12.6: (a) Removing the protective foil from the Velcro tape and (b) mounting the hand at the required position.

Figure 12.7: Fixing hands to the DUT for vertical rotation.

12.5 Laptop Fixture

A fixture to provide horizontal and vertical rotational stability has been designed for laptops, notebooks, and keyboards of various sizes. The fixture can be easily mounted on most common turntables to allow alignment of its rotation axis to the rotation center of the DUT. The back side of the fixture has a feature for fixing the display of the laptop to an opening angle of $110 \pm 5°$, in accordance with CTIA test plan requirements (Chapter L.9.1). On the front is a detachable platform to facilitate positioning the hands on very narrow laptops.



(a) (b)

Figure 12.8: (a) Laptop fixture with (b) laptop and hand phantoms.

Recommended Operation - Testing Mode

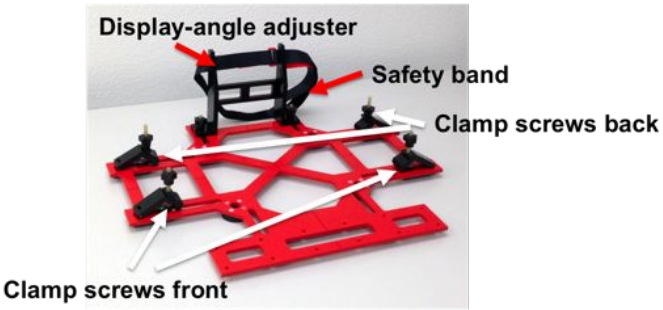


Figure 12.9: Laptop fixture parts.

The following steps will guide you through the recommended procedure for mounting the DUT on the fixture.

- Define the center of rotation of the DUT, which is normallly the three dimensional geometric center. In the case of an open laptop or notebook, this is typically a point in space above the keyboard in front of

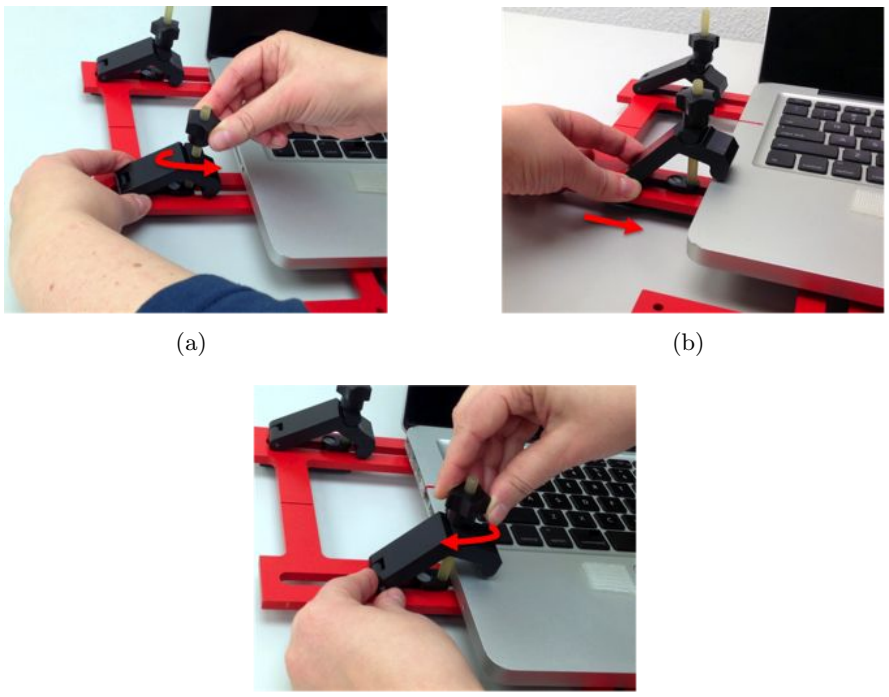
the display. Mark the location of this point on the DUT as shown in the example in Figure 12.10(a).

- Open the DUT and place it on the fixture with the center marks aligned (see Figure 12.10(b)).

(a) (b)

Figure 12.10: (a) Marking the edges of the geometric center on the DUT and (b) aligning with the fixture.

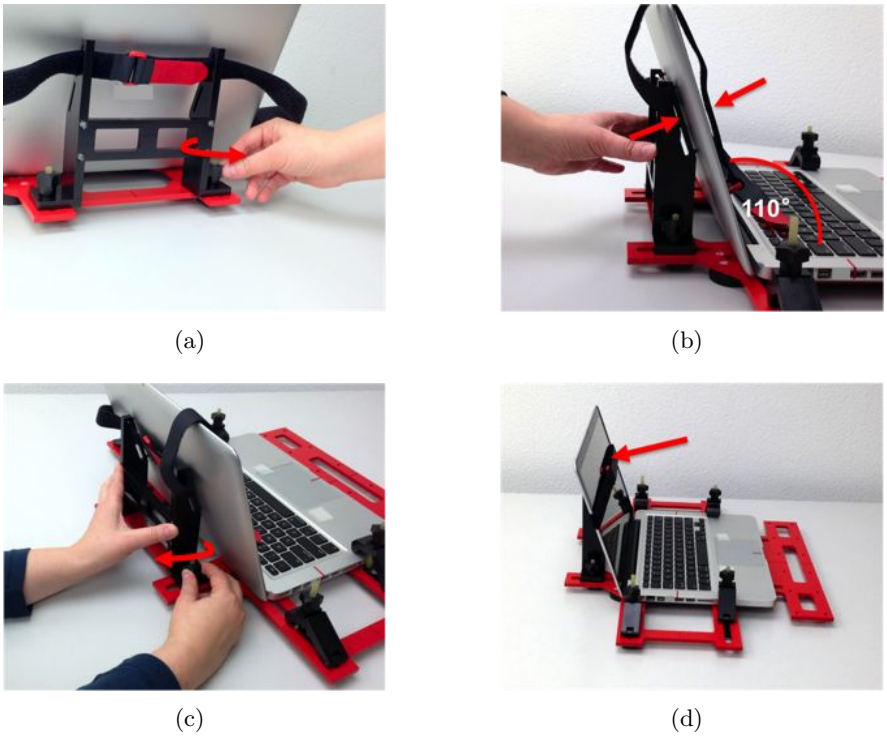
- Loosen the clamp screw to adjust to the height of the laptop (see Figure 12.11(a) and 12.11(b)). First, fix the two clamp screws on the front; then, if needed for stability, also fix the two clamp screws on the back (see Figure 12.11(c)). **Note: To avoid damaging the laptop case, do not over tighten the screws.**
- To adjust the angle of the display, loosen both screws of the display-angle adjuster on the back and align it with the open display (see Figure 12.12(a) and 12.12(b)). The predefined angle is 110°.
- Tighten the screws on both sides and fix the safety band around the display (see Figure 12.12(c) and 12.12(d)).
- Attach the hand phantoms to the Velcro strip (if the position is not yet defined, please follow the recommended procedure described in Section 12.4). Fix the hands to the laptop with the safety band (see Figure 12.13).
- For very small laptops, an extra platform may be needed to provide support for the hand phantoms. In this case, use the white spacers to adjust the height and fix the spacers to the spacer platform with the four red screws (see Figure 12.14).



(a) (b)

(c)

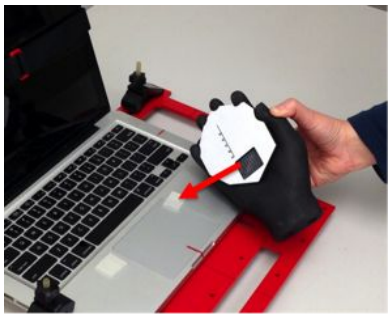
Figure 12.11: (a) Loosening the clamp screw, (b) adjusting the height and position of the fixing point, and (c) tightening the clamp screw.



(a) (b)

(c) (d)

Figure 12.12: (a) Loosening the clamp screw of the display-angle adjuster, (b) aligning with the display, and (c) tightening the clamp screw. (d) Fixing display with the safety band.

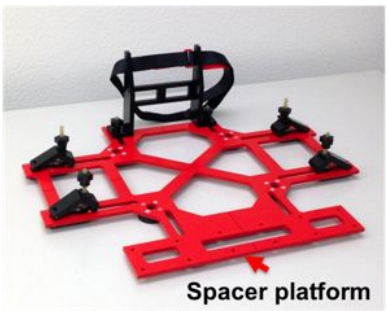


(a)

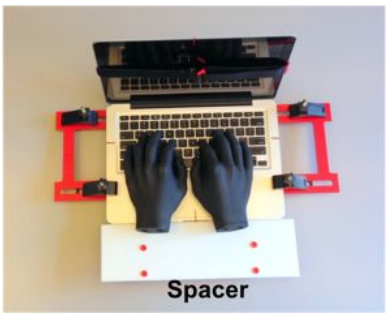
(b)

(c)

Figure 12.13: (a) and (b) Attaching the hand phantoms to the Velcro strip, and (c) fixing with the safety band.



(a)



(b)

Figure 12.14: (a) Spacer platform with (b) holes to fix the spacers with four red screws.

Chapter 13

Travel Case / Car Torso (TCCT) and Transportation Box

13.1 Travel Case / Car Torso (TCCT)

13.1.1 Introduction

The TCCT combines two functionalities. It enables the safe transport of all SPEAG SAM Heads (e.g. SAMV4.5, SAM V4.5CTIA, SAM V4.5BS) and also provides a means to securely mount the SAM Head on a car seat to test communication performance under actual network conditions (see Operation Car Torso).

Note: For safe transport of SAM V4.5 and SAM V4.5CTIA Head Phantoms, it is strongly recommended to remove the liquid from the head phantom and then pack it in TCCT in an additional box with foam filling, e.g. in the TCCT Transportation Box as shown in Section 13.2.

13.1.2 Dimensions

Length	425 mm
Width	324 mm
Height	446 mm
Weight	8.6 kg

13.1.3 Construction

Material: MDF (Medium Density Fiber Board)

Figure 13.1: TCCT

13.1.4 Operation Travel Case

The TCCT provides everything to safely transport all SPEAG SAM Heads (e.g. SAMV4.5, SAM V4.5CTIA, SAM V4.5BS). A rigid foamed form adapted to the SAM Head is installed in the base and in the top-cover of the case. This form keeps the SAM Head in a fixed position during transport (except air-transport).

Note: For safe transport of SAM V4.5 and SAM V4.5CTIA Head Phantoms, it is strongly recommended to remove the liquid from the head phantom and then pack it in TCCT in an additional box with foam filling, e.g. in the TCCT Transportation Box as shown in Section 13.2.

13.1.5 Operation Car Torso

On two sides, the TCCT has a set of four integrated nuts that are compatible with the four 8mm holes in the bottom flange of the SAM Head in dimension and positioning. Operation of the SAM Head on the TCCT is possible in 2 positions depending on the preferred height of the passenger head. Six slots in the opening of the TCCT ensure a simple and secure mounting of the torso on the car seat using the seat belt.

Note: In case of a need for long distance transportation (e.g. by airplane), it is strongly recommended to pack the TCCT

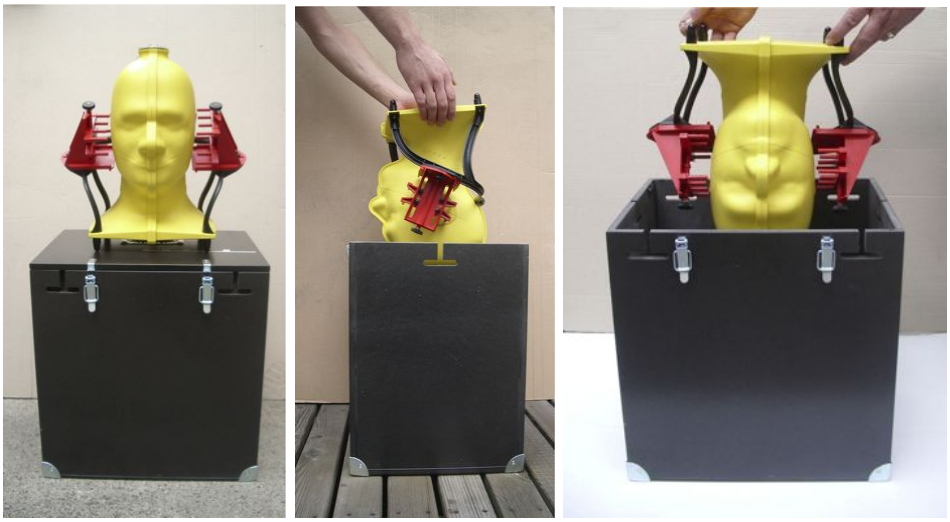


Figure 13.2: Operation Travel Case

in an additional box with foam filling, e.g. in the TCCT Transportation Box as shown below.

13.2 TCCT Transportation Box (TCCT TB)

13.2.1 Introduction and Operation

The TCCT TB is a strong watertight, crush- and dust-proof packing device for safe transportation of the TCCT including SAM Head on airplanes. The box comes with four removable wheels for ease of movement and large, fold-down handles for two person lift.

It is recommended to remove the wheels at airport check-in to avoid damage of the wheels and/or the TCCT TB.

Note: For safe transport of SAM V4.5 and SAM V4.5CTIA Head Phantoms, it is strongly recommended to remove the liquid from the head phantom and then pack it in TCCTTB.

13.2.2 Dimensions

Length	571 mm
Width	569 mm
Height	540 mm
Weight TB only	14.5 kg
Weight TB incl. TCCT	22.1 kg

Figure 13.3: Operation Car Torso

Figure 13.4: TCCT TB: outside view (left) and inside view (right)

13.2.3 Construction

Shell Material: polypropylene
Shell Color: black
Filling Material: custom made foam (polyurethane)

Appendix A

Uncertainty Assessment of SAM-V4.5 Head and SHO Hand Phantoms

A.1 Introduction

The objective of this chapter is to document the general concept and the evaluation techniques of head and hand phantoms uncertainty evaluations according to CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.x. The analysis is consistent with Appendix G and Appendix I of CTIA Test Plan.

A.2 Concept of Phantoms and Positioning Uncertainties

These uncertainty components arise from:

- The tolerance of head shape, shell thickness and dielectric parameters and mounting construction
- The tolerance of hand shape and mounting fixture
- Positioning the phone in the hand and the hand with the phone at the head with respect to the definitions provided in CTIA Test Plan Appendix A [3]

The combined uncertainty of head, hand and EUT positioning in the hand and against the head phantoms is determined as shown in Table A.1.

Table A.1: Standard uncertainties for the head, hand and EUT positioning in the hand and against the head phantoms

Description of uncertainty contributions	**Standard Uncertainty, dB**
Head Phantom Uncertainty	
Hand Phantom Uncertainty	
Head Phantom Fixture Uncertainty	
Hand Phantom Fixture Uncertainty	
Phone Positioning Uncertainty	
Combined Standard Uncertainty (RSS)	

The uncertainty components represent the maximum uncertainty for the determination of TRP and TIS. The measurement uncertainty estimate includes the 700-900 MHz and the 1500-2200 MHz bands and will be conducted for the following endpoints:

- Total Radiated Power (TRP)
- Power radiated over $\pm 45\,^\circ / \pm 30\,^\circ$ degrees near the Horizon (NH-PRP $\pm 45\,^\circ / \pm 30\,^\circ$)
- Upper Hemisphere Radiated Power (UHRP)
- Partial GPS Radiated Power (PGRP)

The selected phones used in the evaluation enables to extrapolate the uncertainty to the entire phone population. Since the evaluation effort per phone can be significant, the total number of phones to be used in the evaluation is limited for practical reasons. The number of phones should be at least six and include at least two monoblock phones (fixed or sliders), two fold phones, two with antennas at the top, and two with antennas at the bottom of the phone.

A.3 Head Phantom Uncertainty

The head phantom uncertainty is the effect of the tolerances of the inner and outer surface shape, the dielectric parameters and the shell thickness, as well as the supporting materials except the head phantom fixture. The transformations of these tolerances to uncertainties for end points defined in Section A.2 have been studied in literature [4]. The following approximations defined in CTIA OTA Test Plan are used to determine the head uncertainty for both orientations, i.e.,

vertical and horizontal orientation, where a rectangular distribution shall be assumed:

$$u_{head\_phantom\_shell}[dB] = c_1 \cdot \left[10 \cdot \log_{10}\left(1 + \left|\frac{\Delta d}{d}\right|\right)\right] \tag{A.1}$$

$$u_{head\_phantom\_permittivity}[dB] = c_2 \cdot \left[10 \cdot \log_{10}\left(1 + \left|\frac{\sqrt{\Delta\varepsilon^2 + \Delta\varepsilon_{unc}^2}}{\varepsilon}\right|\right)\right] \tag{A.2}$$

$$u_{head\_phantom\_conductivity}[dB] = c_3 \cdot \left[10 \cdot \log_{10}\left(1 + \left|\frac{\sqrt{\Delta\sigma^2 + \Delta\sigma_{unc}^2}}{\sigma}\right|\right)\right] \tag{A.3}$$

$$u_{head\_phantom\_shape}[dB] = c_4 \cdot \left[10 \cdot \log_{10}\left(1 + \left|\frac{\Delta shape}{shape}\right|\right)\right] \tag{A.4}$$

The sensitivity factor $c_1 = 0.10$ as determined according to Appendix I and documented in the paper mentioned above. Δd is the maximum deviation from the nominal shell thickness d from the CAD file, whereas the maximum tolerable deviation is $\pm$ 0.2 mm. This tolerance must be verified for an area as wide as $\pm$ 50 mm symmetric to the line connecting the Ear Reference Point to the Mouth Point (line extending from the ear reference point to 20 mm below the mouth point as well as for the surface of the ear). The measurements can be conducted with a properly calibrated inductive thickness measurement instrument.

$\Delta\varepsilon$ and $\Delta\sigma$ are the tolerances from the target relative permittivity and conductivity of the head material, respectively, where the maximum tolerable tolerance shall be 20%. $c_2 = 0.39$ and $c_3 = 0.065$ were determined according to the methodology of Appendix I of CTIA Test Plan and documented in [4].

$\Delta\varepsilon_{unc}$ and $\Delta\sigma_{unc}$ are expanded measurement uncertainties (k = 2) of dielectric parameters according to Appendix G of CTIA OTA Test Plan.

$\Delta shape$ is the tolerance of the inner surface of the shell. If the tolerance is within 2% from that specified in the SAM CAD file provided in IEEE 1528-2002 [5] and maintained in this boundary range during the entire measurement cycle, the effect of the head phantom shape can be neglected, i.e., $c_4 = 0$. If the tolerance is larger, a numerical study as outlined in Appendix I must be conducted to determine $\Delta shape$.

A.4 Hand Phantom Uncertainty

The hand phantom uncertainty is the effect of the tolerance of the shape of the molded hand phantom including the spacer and the tolerance of the dielectric parameters [6]. The material properties of the hand material are evaluated with the following protocol:

1. The hands must be produced together with a cube with side lengths of greater than 40 mm. Each hand must be associated with a reference cube produced from the same material mixture.
2. Slices of at least 3 mm thickness shall be cut on three orthogonal sides of the cube. The other three orthogonal sides remain untreated.
3. Relative permittivity and conductivity shall be measured at ten specified points on the hand exterior surface and on each of the three cut sides of the cube. Exterior and interior averages and standard deviations are calculated according to [3]. The total averages shall then be calculated as the average of exterior and interior values.
4. The hands are acceptable, i.e., meeting the minimal requirements, if:
   - The overall average is within 15% for permittivity target and 25% for conductivity,
   - The standard deviation over all measurements is within 20% for permittivity and 40% for conductivity.
   - The average of each cut surface is within 10% of the overall average for permittivity and 20% for conductivity.
   - The average of the hand surface is within 20% of the overall average for permittivity and 30% for conductivity.

The transformation of these tolerances to uncertainties for the end points defined in Section A.2 must be determined according to Appendix I. The following approximations shall be used to determine the hand uncertainty where a rectangular distribution is assumed:

$$u_{hand\_phantom\_permittivity}[dB] = c_1 \cdot \left[10 \cdot \log_{10} \left(1 + \left| \frac{\sqrt{\Delta\varepsilon_{avg}^2 + \varepsilon_{unc}^2 + (a_1\varepsilon_{std})^2}}{\varepsilon} \right| \right) \right] \tag{A.5}$$

$$u_{hand\_phantom\_conductivity}[dB] = c_2 \cdot \left[10 \cdot \log_{10} \left(1 + \left| \frac{\sqrt{\Delta\sigma_{avg}^2 + \sigma_{unc}^2 + (a_1\sigma_{std})^2}}{\sigma} \right| \right) \right] \tag{A.6}$$

$$u_{hand\_phantom\_shape}[dB] = c_3 \cdot \left[10 \cdot \log_{10} \left(1 + \left| \frac{\Delta shape}{shape} \right| \right) \right] \tag{A.7}$$

$\Delta\varepsilon_{avg}$, $\Delta\sigma_{avg}$, ε_{std}, σ_{std} are the values determined as defined above and ε_{unc} and σ_{unc} are expanded measurement uncertainties (k = 2) of the dielectric parameters according to Appendix G of CTIA Test Plan determined for homogeneous materials. $c_1 = 0.78$ and $c_2 = 0.39$ and $a_1 = 0.5$ were determined according to the methodology of Appendix I of CTIA Test Plan.

$\Delta shape$ is the uncertainty on the end points defined in Section A.2, resulting from the tolerance of the hand phantom shape. Since the hands are usually manufactured within models, the tolerance is 2% and therefore the effect is negligible, i.e., $c_3 = 0$. If the tolerance is larger, a numerical study as outlined in Appendix I of CTIA Test Plan must be conducted to determine $\Delta shape$.

A.5 Hand Phantom Fixture Uncertainty

The hand phantom mounting fixtures uncertainty is the effect of the hand phantom fixtures on the end points defined in Section A.2 compared to the standard configuration with an ideally RF transparent fixture. The effect of the fixture is frequency dependent and is evaluated at the middle channel of the PCS and Cell bands in order to estimate the uncertainty of the 1500-2200 MHz and the 700-900 MHz bands, respectively.

Numerical technique is used to obtain an uncertainty estimate of hand phantom fixture uncertainty. The study is conducted according to Appendix I of CTIA Test Plan by comparing the differences between the end points with and without fixtures.

A.5.1 Simulation Software

The evaluation was conducted using the electromagnetic simulation tool SEMCAD X which satisfies the basic requirements mentioned in CTIA Test plan:

- Import of mobile phone CAD data (typically, >500 parts) as well as head/hand phantoms and fixture data
- Accurate simulation of mobile phones with homogenous head and hand phantoms including effect on impedance, efficiency, and performance
- Position of mobile phone and phantoms with high precision
- Evaluation of end points specified in Appendix G
- Scripting abilities

The simulation software has been validated by the manufacturer in different studies [7] - [10]. In addition, it is further validated by checking the correct evaluation of the end points of dipoles and computation of the benchmark examples referred in Appendix I of CTIA Test Plan.

A.5.2 Phone Models

The number of different phone models used in this study is six and include the following devices:

- Phone1: Monoblock phone with an extended antenna at the top
- Phone2: Monoblock phone with an antenna at the top and embedded in the back of the phone
- Phone3: Monoblock phone with antenna at the bottom
- Phone4: Monoblock (Slider) phone with antenna at the top
- Phone5: Fold phone with an extended antenna at the top
- Phone6: Fold phone with antenna at the bottom

In different studies, each of the phone models are validated by SAR distribution or near-field free space comparison (distance to the surface of the phone less than 20 mm) for different distances from the phone and by TRP and efficiency comparisons.

A.5.3 Numerical Evaluation of Hand Phantom Fixtures Uncertainty

The numerical evaluation compares the differences between the end points specified in Appendix G of CTIA Test Plan with and without fixtures.

The following procedure is applied for Hand Phantom Talk Mode fixture uncertainty evaluation:

1. Import models of the head and hand phantoms into the validated phone model space and set material parameters according to Appendix C of CTIA Test Plan. Note that the appropriate hand phantom is chosen by the device width, its usage mode and its form factor (Appendix A of CTIA Test Plan).
2. Position the phone with respect to the head and hand phantoms according to the procedure defined in Appendix A of CTIA Test Plan.
3. Import model of hand phantom talk mode fixture into the same model space.
4. Position them to operate as fixture and set material parameters.
5. Perform the initial simulation for each frequency band and evaluate the end points specified in Appendix G of CTIA Test Plan.
6. Without changing any simulation settings and discretizations, repeat step 5 without fixture.

The following procedure is applied for Hand Phantom Data Mode fixture uncertainty evaluation:

1. Import model of the hand phantom into the validated phone model space and set material parameters according to Appendix C of CTIA Test Plan. Note that the appropriate hand phantom is chosen by the device width, its usage mode and its form factor (Appendix A of CTIA Test Plan).
2. Position the phone with respect to the hand phantom according to the procedure defined in Appendix A of CTIA Test Plan.
3. Import model of hand phantom data mode fixture into the same model space.
4. Position them to operate as fixture and set material parameters.
5. Perform the initial simulation for each frequency band and evaluate the end points specified in Appendix G of CTIA Test Plan.
6. Without changing any simulation settings and discretizations, repeat step 5 without fixture.

A.5.4 Computation of the Uncertainty

Each phone is simulated with and without mounting structures. Table A.2 and Tables A.4 & Table A.4show the maximum difference determined at the end points specified in Appendix G for Talk Mode and Data Mode fixtures, respectively. These values are converted to a standard uncertainty assuming a rectangular distribution.

Table A.2: Hand Phantom Fixture Uncertainty Assessment

Maximum difference determined at the end points (dB)					
	ΔTRP	**ΔNHPRP**±45°	**ΔNHPRP**±30°	**UHRP**	**PGRP**
Phone1	0.07	0.09	0.20	0.07	0.12
Phone2	0.09	0.08	0.08	0.10	0.05
Phone3	0.11	0.11	0.12	0.12	0.12
Phone4	0.05	0.02	0.03	0.35	0.11
Phone5	0.08	0.23	0.28	0.18	0.09
Phone6	0.04	0.05	0.05	0.19	0.06

Table A.3: Data Mode Fixture V1 Uncertainty Assessment

Maximum difference determined at the end points (dB)					
	ΔTRP	**ΔNHPRP**±45°	**ΔNHPRP**±30°	**UHRP**	**PGRP**
Phone1	0.00	0.04	0.05	0.09	0.05
Phone2	0.07	0.13	0.16	0.15	0.12
Phone3	0.05	0.09	0.10	0.11	0.08
Phone4	0.05	0.12	0.13	0.12	0.10
Phone5	0.04	0.07	0.07	0.11	0.07
Phone6	0.03	0.09	0.09	0.04	0.05

Table A.4: Data Mode Fixture V2 Uncertainty Assessment

Maximum difference determined at the end points (dB)					
	ΔTRP	**ΔNHPRP**±45°	**ΔNHPRP**±30°	**UHRP**	**PGRP**
Phone1	0.00	0.03	0.04	0.08	0.04
Phone2	0.08	0.13	0.15	0.14	0.13
Phone3	0.05	0.08	0.09	0.09	0.07
Phone4	0.05	0.10	0.11	0.10	0.09
Phone5	0.05	0.06	0.05	0.09	0.05
Phone6	0.03	0.07	0.07	0.03	0.04

A.6 Example of Uncertainty Assessment

	a		**b**	**c**	u_i	
Uncertainty Component	**Tol. (± dB)**	**Prob. dist.**	**Div.**	c_i	**Std. unc. (± dB)**	v_i
Head Phantom						
Shell Thickness	0.41	R	$\sqrt{3}$	0.10	0.02	∞
Filling/Liquid Dielectric Contstant	0.28	R	$\sqrt{3}$	0.39	0.06	∞
Filling/Liquid Conductivity	0.33	R	$\sqrt{3}$	0.065	0.01	∞
Geometry/Shape	0.25	N	2	1	0.13	∞
Supporting Structure Uncertainty	0.00	R	$\sqrt{3}$	1	0.00	∞
Combined Head Phantom Uncertainty					0.14	∞
Hand Phantom						
Material Dielectric Contstant	0.26	R	$\sqrt{3}$	0.78	0.12	∞
Material Conductivity	0.65	R	$\sqrt{3}$	0.39	0.15	∞
Geometry/Shape (incl. spacer)	0.00	R	$\sqrt{3}$	1	0.00	∞
Combined Hand Phantom Uncertainty					0.19	∞
Fixtures						
Head Phantom Fixture		R				∞
Hand Phantom Fixture	0.35	R	$\sqrt{3}$	1.00	0.20	∞
Data Mode Fixture	0.16	R	$\sqrt{3}$	1.00	0.09	∞
EUT Related						
EUT Positioning (see G.10.5 of [3])	0.58	R	$\sqrt{3}$	1.00	0.33	
Combined Standard Uncertainty (Head+Hand+Fixture)					0.46	∞

Appendix B

SHO Mounting Equipment (SHO-ME)

B.1 Introduction

SHO Mounting Equipment (SHO-ME) is an add-on to the Mounting Device for Transmitters. It enables SAR assessments with SHO hand phantoms using the DASY system and Twin SAM phantom. With SHO-ME, users can evaluate the influence of the hand on the SAR results of a device under test.

Accurate and repeatable positioning of the transmitter is possible using high precision positioning equipment. Positioning of the transmitter in the SHO hand phantom is performed in the same way as described in the SHO user manual according to the procedure standardized in CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.x.

The instructions given below describe how to mount the hand phantom on the DASY device holder, to place the mobile phone in the hand phantom, and to position the mobile phone against the Twin SAM Phantom head. The instructions below are applicable to brick (candybar) type phones. Similar instructions can be followed for clamshell or PDA type phones. Please consult the OTA user manual for more information.

B.2 Tools Required

None

B.3 Procedure

B.3.1 SAR measurement with hand phantom using DASY system and Twin SAM Phantom

1. Mount the hand phantom on the DASY device holder following the procedure described in Section B.3.2. Exchange hand phantom types as described in Section B.3.3.
2. Place the mobile phone (DUT) into the grip of the hand phantom, following the instructions ofSection B.3.4.
3. Position the DUT against the Twin SAM Phantom in accordance with [11] and [12].
4. Follow Section B.3.5 to ensure that the device is in good contact with the ear of the Twin SAM Phantom.
5. Check that the final position of the DUT looks as shown in Fig. B.1. It should not be as shown in Fig. B.2 or Fig. B.3.

Figure B.1: **Correct positioning**. The DUT is in the cheek position and the back of the DUT is in good contact with the hand phantom spacer

B.3.2 Installing the Hand Phantom on the DASY Device Holder

1. Loosen the black screw as shown in Fig. B.4(a).
2. Remove the device holder top from the two white poles as shown in Fig. B.4(b).
3. Install the hand phantom adapter onto the two white poles as shown in Fig. B.5.

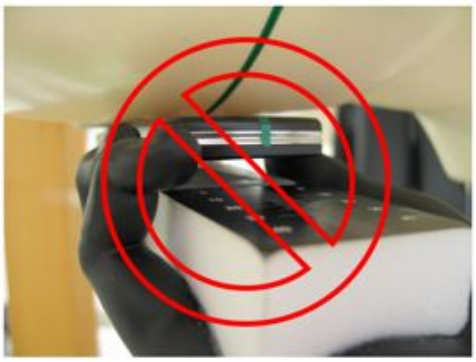


Figure B.2: **Incorrect positioning**. The back of the DUT does not make good contact with the hand phantom spacer.

Figure B.3: **Incorrect positioning**. The DUT is not in the correct cheek position. For thin phones, the thumb of the hand phantom will make contact with the Twin SAM phantom before the DUT is in the cheek position. Hand phantom fingers are flexible and should be moved slightly to obtain correct cheek position.

B.3.3 Exchanging Hand Phantom Types

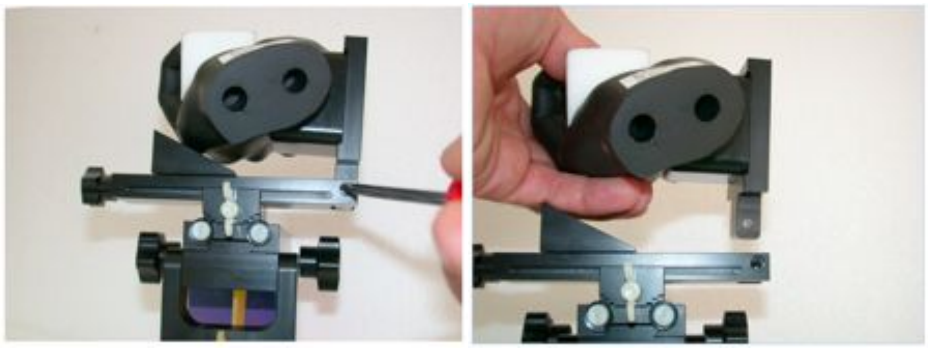
1. Loosen the black screw as shown in Fig. B.6(a).

2. Remove and exchange the hand phantom and re install the black screw carefully.

(a) (b)

Figure B.4: (a) Loosening the black screw, (b) Device holder removed.

Figure B.5: Installing the hand phantom adapter.



(a) (b)

Figure B.6: (a) Removing the black screw, (b) Exchange the hand phantom type.

B.3.4 Placing the DUT in the Grip of the Hand Phantom

1. Place the DUT on the alignment tool B and fit it into the corner between the slab and the guiding strip. Slide the DUT down until it reaches the angled corner, as shown in Fig. B.7(a).
2. Record the chin length from the scale on the alignment tool (Fig. B.7(a)).
3. Place the DUT on the hand phantom spacer and between the fingers of the hand phantom. The bottom of the DUT should align with the chin length recorded in step 2, as shown in Fig. B.7(b)).

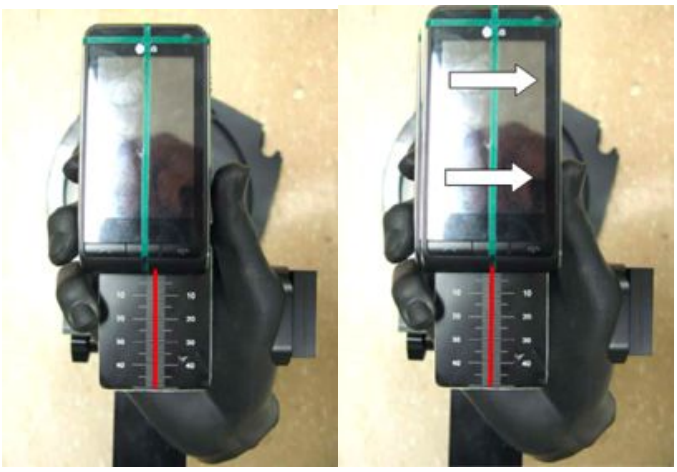
(a) (b)

Figure B.7: Positioning DUT relative to the hand phantom.

4. While keeping the DUT in the position defined in the previous step, ensure that the vertical centerline of the DUT is oriented along the length of the hand phantom spacer, as shown in Fig. B.7(b). The horizontal alignment of the device should be according to Fig. B.9.
5. While keeping the DUT in the position defined in the previous steps, make sure that the index finger is in good contact with the DUT (Fig. B.8(c)). It is recommended to use the 3M dual lock Velcro strip provided with the hand phantom to fix the DUT to the hand phantom.

(a) incorrect rotation (b) correct rotation (c) correct position

Figure B.8: (Positioning DUT relative to the hand phantom.



(a) misaligned (b) correct alignment

Figure B.9: Horizontal alignment of the DUT relative to the hand phantom. (a) incorrect alignment (note that the vertical centerline of the DUT in green is not aligned with the red line representing the centerline of the hand phantom spacer), (b) correct alignment.

B.3.5 Angle Adjustment of Hand Phantom for Phone Alignment against Twin SAM Phantom Ear

For adherence to the device positioning procedures of [11] and [12], the DUT must be in good contact with the ear on the Twin SAM phantom. This means that the horizontal line on the DUT (see Fig. B.8) and the

edge of the ear along the N-F line must be parallel. To ensure this, angle adjustment of the hand phantom is necessary.

Important: the back of the device must be in good contact with the hand phantom spacer. Do not rotate the DUT in the hand phantom.

Before rotating the hand phantom, ensure that the vertical centerline of the DUT is aligned with the green M-B line on the Twin SAM phantom. The hand phantom can be shifted to the left or right by loosening the wing screw shown in Fig. B.10.

The way to rotate the hand phantom is to use the wedge shown in Fig. B.10. The hand phantom is hinged on the hand phantom fixture. Movement of the wedge to the left or right rotates the hand. This is done by rotating the wedge screw.

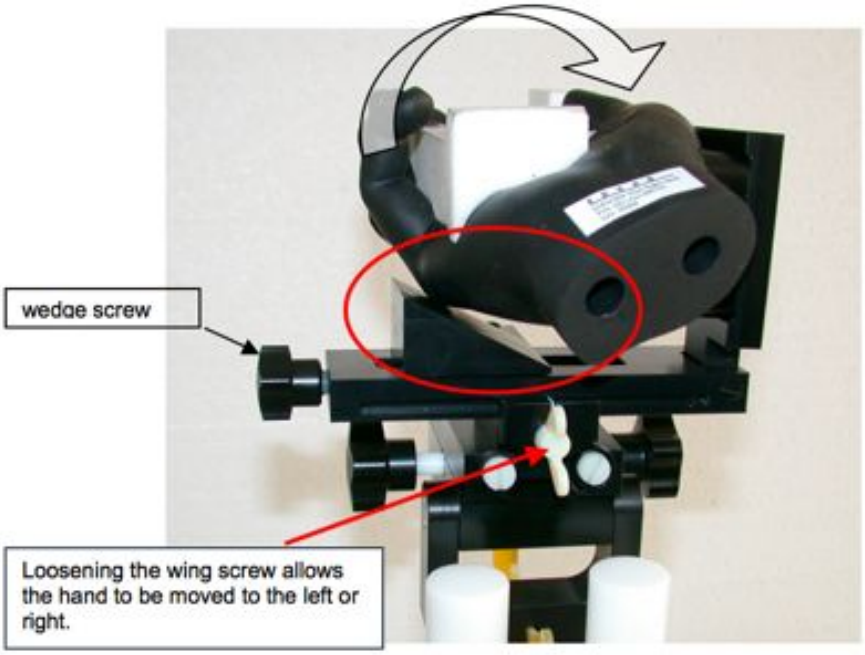


Figure B.10: Wedge of the hand phantom fixture.

Bibliography

[1] M.C. Gosselin et al, *Estimation Formulas for the Specific Absorption Rate in Humans Exposed to Base Station Antennas*, 2011.

[2] C.C. Gordon et al, *Anthropometric survey of U.S. Army personnel: summary statistics interim report*, 1989.

[3] CTIA Test Plan for Wireless Device Over-the-Air Performance, Revision 3.x.

[4] Ofli E., Chavannes N., and Kuster N., *The Uncertainties and Repeatability Limitations of Transmitter and Receiver Performance Assessments Posed by Head Phantoms*, Proc. IEEE International Workshop on Antenna Technology (IWAT06), pp. 349-352, New York, 2006.

[5] IEEE, 1528-2002 SCC34 Draft Standard: Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Body Due to Wireless Communications Devices: Experimental Techniques, April 2002.

[6] Li C-H., Ofli E., Chavannes N., and Kuster N., *The Effects of Hand Phantom on Mobile Phone Antenna OTA Performance, Proc. Second European Conference on Antennas and Propagation*, EuCAP 2007, Edinburgh, UK, November 11 - 16, 2007.

[7] N. Chavannes, R. Tay, N. Nikoloski, and N. Kuster, *Suitability of FDTD-based TCAD tools RF design of mobile phones*, IEEE Antennas and Propagation Magazine, vol.45, no.6, pp.52-66, 2003.

[8] N. Chavannes, R. Tay, F. Nunez, E. Ofli and N. Kuster, *Virtual Prototyping and Failure Mode and Effect Analysis (FMEA) in Industrial Design Processes on the Basis of Mobile Device Terminals*, The Second European Conference on Antennas and Propagation, EuCAP 2007, pp.1-5, Nov. 2007.

[9] P. Futter, N. Chavannes, R. Tay, M. Meili, A. Kingenbock, K. Pokovic and N. Kuster, *Reliable Prediction of Mobile Phone Performance for Realistic in-use Conditions using the FDTD Method*, Antennas and Propagation Magazine, IEEE, vol.50, no.1, pp.87-96, Feb. 2008.

[10] Li C-H., Ofli E., Chavannes N., and Kuster N., *Effects of hand phantom on mobile phone antenna performance*, IEEE Transactions on Antennas and Propagation, vol. 57, pp. 27632770, 2009.

[11] IEEE Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communication Devices: Measurement Techniques, IEEE Standard 1528-2003.

[12] Human Exposure to Radio Frequency Fields from Hand-Held and Body-Mounted Wireless Communication DevicesHuman Models, Instrumentation, and ProceduresPart 1: Procedure to Determine the Specific Absorption Rate (SAR) for Hand-Held Devices Used in Close Proximity to the Ear (Frequency Range of 300 MHz to 3 GHz), IEC Standard 62209, Feb. 2005.